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ENGINEERING STUDY FOR THE VOLUME REDUCTION SYSTEM DEWATERING AND STABILIZATION SYSTEM FOR THE ENVIRONMENTAL RESTORATION STORAGE AND DISPOSAL FACILITY

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CENPW INFORMATION RELEASE REQUEST (CEIRR)

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ENGINEERING STUDY FOR THE VOLUME REDUCTION SYSTEM DEWATERING AND STABILIZATION SYSTEM FOR THE ENVIRONMENTAL RESTORATION STORAGE AND DISPOSAL FACILITY

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

1.1.1 ERSDF Description

The U.S. Department of Energy (DOE) has tasked the U.S. Army Corps of Engineers (USACE) to perform detailed planning for the development of the conceptual design for the Environmental Restoration Storage and Disposal Facility (ERSDF) at the Hanford site near Richland, Washington. The production of plutonium and related activities since 1943 have resulted in significant environmental (primarily soil) contamination on the Hanford site. The ERSDF will serve as the disposal facility for the majority of wastes excavated during remediation of waste management sites in the 100, 200 and 300 areas of the Hanford facility. The initial work was designated by Westinghouse Hanford Company (WHC) as project W-296, and is defined as the design and construction of facilities for the disposal of waste generated through the year 2001. The operation of the facility will be performed under another project. Only waste from the 100 and 300 areas will be disposed in W-296. The USACE has tasked Montgomery Watson to conduct the engineering study under Delivery Order No. 0017, under the indefinite delivery order (IDO) contract number DACW68-92-D-0001, with the Walla Walla District.

The current concept for the ERSDF calls for burial of remediation derived waste in trenches up to 33 feet deep, covered with a 15-foot-thick cap. This cap, referred to as the Hanford Barrier, is specifically designed for this site to prevent infiltration and limit access to the waste for as long a reasonably possible. Some or all of the waste disposal units may be lined, and some or all of the waste may be buried in containers, depending on the nature of the waste and the outcome of future regulatory determinations. Along with the disposal units, the ERSDF will include waste handling and transportation faculties such as an administration building.

It is anticipated that the ERSDF will be located near the 200 areas, in the center of the Hanford site. This location was selected due to the central location and the favorable geologic conditions associated with this portion of the Hanford site. The site location is currently being evaluated by DOE.

1.1.2 VRS Dewatering/Stabilization System

Contaminated soil is a major element of the disposal problem at Hanford, because of the very large volumes of soil involved. The estimated total volume of contaminated waste soil is approximately 30 million cubic yards (CY) (Trost and Roeck 1993). Based on information contained in Moore 1993 we assumed that most of this soil is coarse river overbank deposits, with approximately five percent fine sand and silt. A VRS soil washing study is currently being prepared by the WHC Environmental Engineering group. A basic premise of that study asserts that most radioactive soil contamination occurs as small particles and that these particles preferentially attach themselves to the fine fraction in soil. Recognizing these characteristics, a volume reduction system (VRS) was proposed for the remediation of soil contamination. As proposed the VRS would involve *washing* the soil at the remediation site. The washing process would separate the fines from the coarse fraction of the soil, thereby achieving up to a theoretical 95 percent volume reduction. The resulting mixture of fines and water would be treated and disposed of in some way at the ERSDF. The course fraction, assuming it is free of contamination, would be returned to its point of origin. Of the estimated 30 million CY of waste, only a fraction will be suitable for soil washing.

The contaminated soil waste resulting from the VRS soil washing will be disposed at the ERSDF. It may or may not be isolated in a separate ERSDF trench. The VRS waste is addressed separately from other ERSDF waste because of the unique nature of the material properties and the contamination. The VRS waste may be disposed in a separate facility adjacent to the main ERSDF landfill, or it may be incorporated into the ERSDF waste and disposed in the same location. The method of disposal depends on the physical characteristics of the waste, the disposal criteria and the applicable regulations. This report addresses the engineering and regulatory considerations associated with the VRS waste. The need for treatment of the waste water resulting from VRS dewatering at the ERSDF is evaluated in a separate design study, Engineering Study for the Decontamination and Wastewater Treatment Facility for the Environmental Restoration Storage and Disposal Facility, DOE/RL/12074--10 Rev. 0. Any wastewater resulting from VRS dewatering at the ERSDF will be treated in the same manner as the wastewater addressed in DOE/RL/12074--10 Rev. 0.

1.2 OBJECTIVES OF THIS ENGINEERING STUDIES REPORT

In general, the objective is to establish disposal criteria and to identify promising disposal methods which meet those criteria. Specific objectives of this report include:

1) Define the expected characteristics of the waste stream;

2) Estimate, at a preliminary level, the criteria for dewatering and stabilization;

3) Identify reasonable alternative disposal methods that achieve the objectives and meet the criteria;

4) Compare the alternative disposal methods on the basis of cost and performance, including the sensitivity of the results to uncertainties in the input parameters;

5) Identify the preferred alternative, including a basis for the selection.

2.0 DESIGN CRITERIA

2.1 WASTE STREAM CHARACTERISTICS

2.1.1 Methods of Delivery

VRS waste will be delivered to the ERSDF facilities in reusable containers transported via truck or train. Details of the methods to be used to empty and decontaminate the containers are addressed in separate engineering studies for the ERSDF.

2.1.2 Design Delivery Rates

In order to provide a uniform basis for the evaluation and comparison of alternative disposal methods, the waste quantities, delivery rates and characteristics must be known or assumed. Because the results of field testing of soil washing equipment are not yet available, and remediation waste is only partially characterized, data regarding VRS waste is not available. For this reason assumptions were made regarding VRS waste quantities, delivery rates and characteristics which are based on preliminary projections and estimates.

The assumed maximum delivery rate for VRS waste is 15 containers per shift. For half of each year (summer) operations will include two shifts per day; in winter the shorter periods of daylight will limit operations to only one shift per day. The maximum annual delivery rate is 90,000 CY. The total volume of waste delivered to the site over the life of the landfill is 750,000 CY. These delivery rates are summarized in Table 1.

Table 1. Summary of Assumed VRS Waste Delivery Quantities and Rates.

Duration	Max. No. of Containers	Max. Waste Volume (CY)	Capacity Factor(1)	Bulk Weight(2) (tons)	Weight of Water(3) (tons)	Water Volume (cu-ft)
per SHIFT	15(4)	270	1.00	255	51	1,635
per DAY-Summer	30	540	1.00	510	102	3,270
per DAY-Winter	15	270	1.00	255	51	1,635
per YEAR	5,850	90,000	0.85	85,050	17,010	545,191
per 10 YEAR LIFE	58,500	750,000	0.71	708,750	141,750	4,543,269

(1) Ratio of the expected delivery rate to the maximum delivery rate.
(2) Assumes the bulk density in the container will be 70 pounds per cubic foot (pcf).
(3) Assumes the water content of the waste will be 20 percent by weight.

The volumes of material in the proposed landfill and the quantity of water that must be removed or stabilized is sensitive to the assumed density of the incoming waste. We have assumed that the waste will arrive in the container in a relatively loose state: approximately 70 pcf bulk density. This is a net value within the container, including any airspace which exists above the waste. Later, when the waste is placed into the landfill, the density is assumed to be much greater: approximately 100 pcf, dry density. Thus, the waste will realize a 30 percent volume reduction during disposal due to compaction. These issues are discussed in more detail later in this report.

2.1.3 Soil Properties

Assumptions regarding soil properties were made based on the data contained in Trost and Roeck 1993, and Moore 1993.

2.1.3.1 Grain Size. The soil being delivered to the facility will be primarily silt size with some fine sand. Although radioactive contamination is expected to be associated only with the silt size materials, a small amount of fine sand will be included because of limitations in the screening methods. The washing process will include a 6-inch grizzly (coarse screen) followed by a 1-inch screen which will feed its underflow to a modified Trommel (cylindrical rotating) screen containing a 2-mm screen. The Trommel underflow will feed a final polishing screen with a 0.4-mm opening. The grain size distributions of the various screens are shown graphically in Figure 2-1.

2.1.3.2 Moisture Content. The initial steps in dewatering will be performed at the soil washing facility outside the ERSDF. The slurry leaving the washing mechanism will be in the range of 2- to 5-percent solids by weight. The initial dewatering will be done using thickeners which will produce an underflow at approximately 50 percent water by weight. This relatively thick slurry will proceed to a filter press or similar equipment that will reduce the water content further to approximately 20 percent by weight. This is the expected water content presented in the FDC (Moore 1993). In conversations with various WHC personnel, they indicated that the literature of the filter press manufacturers also suggest that the expected water content of filter press discharge would be approximately 20 percent water by weight. Such a water content is consistent with basic physical principles. The filter press extracts water from the soil by squeezing it to saturation and beyond, thus forcing water from the soil. Following pressing, the soil is removed from the filter press and, during removal, it expands. The expansion introduces air into the soil and the saturation level decreases. However, upon sufficient recompaction, the same soil would again become saturated.

If a soil has a specific gravity of 2.65 (typical average value), a water content of 20 percent by weight, and a dry density of 100 pcf, the soil is essentially saturated. There are no air-filled voids in the soil. A graph showing the relationship between soil moisture expressed by volume and weight as a function of dry density is presented in Figure 2-2.

Due to the expected variation in the soil grain size distribution of the waste, occasional shipments of waste may be substantially different from the waste described above. However, because of the methods of dewatering, the performance characteristics of these wastes are unlikely to be significantly different. Fine-grained (clayey) soils generally have higher field capacities (ability to hold water) and saturated moisture contents than well-graded and more granular soils. If clayey soils are encountered, the moisture content of the waste may be substantially higher than 20 percent by weight. However, these materials also have higher field capacities. The filter press will be dewatering these soils by squeezing them to 100 percent saturation, at a density which is similar to that which can be achieved in the landfill. Thus, the clayey wastes are not expected to generate more leachate than the more common sandy-silt wastes.

2.1.3.3 Field Capacity. The field capacity of the waste is an important parameter because leachate from the landfill is important to the design. Field capacity is the moisture content to which the soil will drain from a saturated state. Conversely, leachate will not be produced from a soil until the moisture content rises to at least the field capacity.

The typical relationships between soil texture and field capacity are shown on Figure 2-3. The values shown on Figure 2-3 are for agricultural soils; the line labelled "porosity" expresses the point of 100-percent saturation, which depends on the degree of compaction as well as the water content. For VRS waste (sandy silt), the field capacity is expected to be about 40 percent by volume, which corresponds to almost 100-percent saturation at a density of 100 pcf. For fine-grained VRS waste which is highly compacted, the "porosity" line (Figure 2-3) is expected to be nearly coincident with the field capacity. The same VRS waste in a slightly looser state would likely have a moisture content which is slightly below the field capacity and substantially below 100-percent saturation.

The actual moisture density relationships for the VRS waste must be defined by laboratory testing. The generalized characteristics discussed herein are applicable to typical soils; however, the expected variations in moisture characteristics with soil type are substantial and may result in conclusions different from those in this report.

2.1.3.4 Variability. There is a potential that some waste will be mishandled or that the equipment will not operate correctly, resulting in an occasional container with waste which has a moisture content much higher than the expected 20 percent by weight. The ERSDF should be capable of handling this occurrence, through dewatering methods or by rejecting the waste using a waste acceptance criteria.

2.2 OPERATIONAL CRITERIA

2.2.1 Particulate Emissions

There are several emissions considerations. These include on-site radiological doses, off-site doses, and non-radioactive fugitive dust. The risks associated with these contaminant pathways have been qualitatively evaluated through discussions with WHC personnel and other contractors.

Off-site dose estimates due to landfill operation suggest that this pathway and its resulting doses are insignificant. The contaminant concentrations are too low and the exposure durations are too short to produce an unacceptably high dose in any receptor off-site.

The on-site radiological dose issues related to dust are potentially more significant. The dose limit defined by DOE Order 5480.11 for exposure limits of radiation workers is 500 mrem/year. Radiological waste characterization data were not readily available to demonstrate that the site workers would be exposed to less than this dose limit. Hence, control of airborne dust within the landfill may be required. One potential method is application of surfactants and binders.

There are several commercial dust suppression agents available which could be used on the waste. A partial list of agents, application rates, and costs is presented in Table 2.

2.2.2 Placement, Spreading, and Compaction Equipment

The equipment and procedures used to place the waste in the landfill and then to compact it must meet health and safety requirements for the equipment operators and other site personnel. The expected working conditions on the site should be defined by a risk assessment. The appropriate type of equipment will be selected depending on the results of that risk assessment.

Three general possibilities exist: first, remote (robot) operation of equipment; second, retrofitting the trucks, graders, compactors and other machinery with filtration equipment which will protect the operators and meet health and safety standards; and third, no special action required.

Remotely operated machinery was evaluated for the 200-BP-1 Operable Unit Feasibility Study. This work concluded that machinery of this type would increase costs of excavation

Table 2. Dust Suppression Agents.

Company	Product Type/ Produce Name	Cost	Cost/Acre	Application Rates
Dow Chemical	Calcium Chloride/			
	Pelledow	$325/ton	$1,040	1.32 lbs/sy
	Dowflake	$329/ton	$1,200	1.5 lbs/sy
Witco Chemical Co.	Petroleum based/			
	SC250	$150.85/ton	$1,170	0.35 - 0.40 gal/sy
	SC800	$135.85/ton	$2,640	0.75 - 1.00 gal/sy
Johnson & March	Surfactant/			
	MR	$6/gal	na	No suggested application rates
	MR2040	$7.25/gal	na	
WRR Industries	Magnesium Chloride/			
	Dust Guard	$620/ton	$1,000	1.6 ton/acre
Chemstar Lime Co.	Lime based/			
	Poz-o-Cap	$180/ton	$180	1 ton/acre
Georgia-Pacific	Lignin Sulfonate/			
	Lignosite	$0.19/gal	$226	1,200 gal/acre
American Cyanamid	Polyvinyl Emulsion/			
	Aerospray 70A	$0.63/lb	$51,000	0.25 gal/sy - 2 gal/sy

by factors of 2 or 3 due to low productivity. In addition, it is considered problematic to maintain a sufficiently high quality of compaction, particularly where large, bulky waste objects must be buried within the contaminated soil.

Retrofitting the machinery with filtration equipment is a feasible alternative. The retrofit would consist of provisions for an airlock entry for the cab of each piece of equipment. The interior of the cab would be maintained at a positive pressure using makeup air supplies through a HEPA filter. Each cab would also be equipped with an emergency air supply to be used in the event of power failure. Direct radiation exposure would be limited by installing shielding in the cab walls, floor and roof.

Whatever is indicated by the risk assessment as the appropriate equipment and procedures, it is likely to apply to nearly all of the alternatives since most involve the placement of exposed radioactive waste. For this reason it is unlikely to affect the relative cost of disposal for the alternatives.

In the development of alternatives (Section 3.0), and in cost estimating (Section 4.3), it has been assumed that no special equipment was necessary to protect workers from wind blown dust. If some protection is required, it will likely be required of all alternatives, and will increase the cost of disposal equally.

2.3 PHYSICAL CRITERIA FOR FINAL DISPOSAL

The waste disposal methods proposed require that the waste perform in certain ways, which are dictated by its in-place physical and chemical characteristics. The performance requirements and characteristics discussed in the following paragraphs are important in the development of waste disposal criteria.

2.3.1 Settlement Potential

After the waste is in place and the permanent cover (Hanford Barrier) is constructed, the settlement of the waste must not be large enough to cause significant disturbance of the cover such that the effectiveness of the barrier is compromised. Based on discussions with the designers of the barrier, we understand that it will be constructed at a slope of 2 percent. The performance of the barrier is not changed significantly until the slope is flattened to 1 percent. Therefore a settlement which permits a slope change from 2 percent to 1 percent is the maximum allowable. If the side slope of the landfill liner is 3H:1V (horizontal:vertical) as planned, the allowable 1 percent slope change translates to a maximum allowable settlement of 3 percent.

This criterion is limited to long-term creep settlement of the waste since most settlement of the unsaturated waste will occur prior to construction of the Hanford Barrier. A 3 percent settlement is relatively large compared to the expected settlements. A typical dam design provides a conservative allowance of 1 percent for settlement of the embankment and foundation following construction, including primary consolidation and settlement of the saturated soils. Creep settlements are expected to be at least one order of magnitude less than primary settlements.

In summary, settlements are not expected to be a significant issue if the waste is compacted at least modestly using construction equipment and in lifts of 12 inches or less. Settlements approaching the criterion limits are not expected unless the waste is end-dumped without any compactive effort.

2.3.2 Disposal of Liquid Effluent

No free liquids will be disposed in the VRS landfill, in compliance with Hanford Solid Waste and RCRA requirements. The Hanford Site Solid Waste Acceptance Criteria (Willis and Triner 1991) states in Section 4.5.1.1 that low level waste must not contain free liquids. If liquids are bound by absorption, the quantity of absorbent must be sufficient to absorb twice the volume of liquid potentially present. RCRA rules are similar. Although these rules are generally applied to waste which will be placed in drums prior to disposal, they indicate the desirability of providing absorption capacity in excess of that which is required to hold the liquids in the matrix.

2.3.3 Permeability

In general terms, low permeability is preferred; however, infiltration which reaches the waste will begin to raise the water content and, once the waste reaches its field capacity, flow will occur, generating leachate. This will occur regardless of the permeability of the waste. Therefore, permeability is fundamentally irrelevant to the long term performance of the system.

2.3.4 Shear Strength

The shear strength requirements of the waste are based on the need to operate equipment on the waste and to construct sloped embankments using the waste while maintaining a reasonably conservative factor of safety against a failure within the waste. The constructed waste embankments will probably have maximum slopes of 3H:1V, or approximately 18.5 degrees. Based on infinite slope theory, a cohesionless waste material must have an angle of internal friction of at least 26.5 degrees in order to maintain a factor of safety of 1.5. From our experience, materials similar to the VRS waste should have friction angles in excess of 26.5 degrees with only modest compaction.

2.3.5 Total Water Content

The selection of a water content criterion was based on two conflicting considerations. To provide maximum compaction, the moisture content should be "optimum" as defined by a Proctor or Modified Proctor density test. The optimum moisture is that which produces the maximum density with a prescribed compactive energy. The optimum moisture tends to produce the strongest possible fill, with the lowest potential for settlement; fills placed wet of optimum have the lowest permeabilities. Based on our experience with similar materials, the optimum moisture content for the VRS waste is likely to be approximately 20 percent moisture by weight or perhaps slightly less. If the VRS waste is spread and compacted as it is dumped from the containers, the resulting fill is likely to be at optimum moisture with a dry density of approximately 100 pcf, with a correspondingly high strength and low settlement potential. However, the material will also be very nearly 100-percent saturated and at its field capacity; thus, precipitation falling on the fill or leakage reaching the top of the fill through the Hanford Barrier would begin to generate leachate relatively quickly, since the soil has very little capacity to absorb moisture.

In order to reduce the potential for leachate production, the waste should be provided additional moisture absorption capacity by reducing its in-place moisture content to a level below the field capacity. If the VRS waste is dried to a moisture content which is, say, 20 percent by volume less than its field capacity, the waste will provide a significant delay in the rate at which barrier leakage reaches the base of the landfill. For example, if the VRS waste is 30-feet thick, and the moisture is 20 percent by volume less than field capacity, the waste can absorb 6 feet of water before leachate will appear at the base, assuming no unsaturated transport by diffusion or vapor migration. Discussions with the personnel modelling the performance of the Hanford Barrier indicate that the estimated infiltration rate through the barrier will be between 1 cm/year and zero. Assuming a rate of 0.1 mm/year, a simple water storage analysis indicates that the waste could absorb more than 18,000 years of barrier leakage, so the lower moisture content appears to be a significant benefit. Recognizing that this is an extremely simple analysis, it is nevertheless considered important to increase the water storage capacity of the waste to the extent feasible.

In summary, the moisture content selected as the disposal criterion should be relatively high to increase strength, and to decrease settlement potential and permeability. Conversely, the selected moisture content should be low to reduce the potential for leachate production. As discussed in previous section, the considerations of strength, settlement and permeability are minor. Strength and settlement criteria should be achievable at a range of moisture contents which are dry of optimum. There are no permeability criteria. Consequently, the leachate production criterion is the most significant. Therefore, the maximum allowable water content of any soils waste placed in the landfill will be a function of its field capacity. For this reason, the maximum water content is set at 20 percent by volume less than the field capacity. Since no laboratory data are available regarding the field capacity of the VRS waste, the criteria is assumed to be satisfied if the water content of the waste or blended waste is 20% by volume, which is approximately half of the moisture content of the incoming VRS waste.

The moisture content criterion was selected without the benefit of an analytical evaluation of the relative costs or risks involved. A more formal analysis should be completed as part of future design efforts.

2.3.6 Stabilization

The conceptual objective of stabilization is to bind water and radioactive fines into a soil matrix that will prevent movement of contaminants as a result of free water movement through the matrix. Non-bound water is believed to be free of radioactive contamination.

2.3.7 Retrieval

Retrieval of the ERSDF waste is not a consideration. The ERSDF, including the VRS waste disposal facility, is considered permanent disposal.

2.3.8 Summary

The two waste performance characteristics which are of primary importance are settlement and moisture absorption capacity. Settlement is important because settlement of the waste has a significant influence on the integrity of the Hanford Barrier. However, settlement is not expected to be a problem as long as the waste is moderately compacted. The moisture absorption capacity of the waste, influenced primarily by its water content, has a significant influence on the number of years before leachate flow begins from the base of the landfill. For the purpose of alternative comparison, a water content criteria was establish: the water content of the compacted VRS waste must be 20 percent by volume less than the field capacity, which provides a water absorption capacity equal to 20 percent of the depth of the waste.

3.0 DEVELOPMENT OF ALTERNATIVES

3.1 BACKGROUND

3.1.1 Alternative Disposal Methods

In an effort to find a suitable disposal method for all the VRS waste, alternative methodologies were developed. Each of these methods was designed to meet the objectives for waste disposal set out in Section 2.0. The success of each alternative in achieving the disposal criteria was evaluated and compared.

The following alternatives were identified and are discussed below:

- Expanding existing facilities that are used to reduce the moisture content of waste.
- Adding chemicals to bind or absorb the moisture in the waste.
- Blending the waste with drier soil to reduce the moisture content.
- Evaporating moisture from the waste in a landfill.
- Modifying dewatering methods already used at the soil washing facility to produce a drier product.
- Using mechanical dewatering methods at the ERSDF site.

3.1.2 Size Requirements

In order to compare different alternatives, conceptual designs were developed for each alternative which meet the same assumed size requirements. All of the alternatives must be capable of disposing of the entire 750,000 CY volume of waste. All of this waste is to be disposed below grade. Assuming a lined landfill, the side slopes will likely be limited to 3H:1V for stability reasons. Using these general parameters, the relationship between the depth, length and width of the required landfill can be established. To provide an initial estimate of the dimensions of the landfill, a relationship between required floor length and floor width was determined assuming the depth from the ground surface to the floor of the landfill is 33 feet. The range of possible lengths and widths is presented graphically in Figure 3-1. As an example, if the floor width is 250 ft, the floor length must be approximately 1600 ft in order to provide a total volume of 750,000 CY. A landfill of approximately these dimensions is assumed for all alternatives requiring a separate VRS landfill, and is presented in plan and section on Figure 3-2. A more detailed examination of alternative landfill dimensions is presented in Appendix B.

3.2 EXPANSION OF EXISTING TREATMENT FACILITIES

3.2.1 Concept

This alternative involves the expansion of the existing facilities for the treatment of soils with excessive water content to a scale which can accommodate the entire VRS waste stream. Discussions with WHC personnel indicate that a central facility does not currently exist for the treatment of such wastes. Rather, wastes are treated for excess liquids at the point of generation, in accordance with the Hanford Site Solid Waste Acceptance Criteria (Moore 1993). Free liquids are stabilized using one of the approved absorbents listed in Appendix K of the Acceptance Criteria. The absorbents are generally referred to by Hanford Site personnel as "kitty litter." There is no requirement that the absorbent be incineratable because VRS disposal is permanent. The resulting matrix is placed in a container, usually a 55 gallon drum, and transported to the point of disposal.

Scaling up the existing treatment methods would involve a very large facility for the filling of drums. Assuming that the volume of the waste increases by 10 percent due to the addition of an absorbent, the daily production of drums, at the maximum daily capacity of 540 CY/day, would amount to 2,479 drums per day, or approximately 2.5 drums per minute. Machinery to handle drums at this rate would be complex and expensive. A covered building would be required.

Once the VRS is stabilized and containerized it would be added to the ERSDF waste stream and disposed in the ERSDF trenches, surrounded by waste soil or interim cover.

3.3 CHEMICAL ADDITIVE TREATMENTS

3.3.1 Concept

Wet VRS waste delivered to the site could be mixed with relatively small quantities of a chemical additive which would stabilize some or all of the water contained in the waste. The resulting mix would meet the disposal criteria by reducing the unbounded interstitial water and permeability, and by increasing the shear strength and resistance to settlement. All mixing described in this alternative was assumed to occur on the surface of the landfill, immediately above previously compacted waste. Many additives were considered, including Cement, Lime, Phosphoric Acid, Fly Ash, Iron and Aluminum Oxides and others. Those additives that could feasibly be applied to VRS waste were identified; the others were not addressed. Three types of additives were selected for consideration: 1) cement as soil-cement and fly ash used as cement, 2) lime, and 3) absorbents as a general class of additives. These are discussed separately below:

3.3.1.1 Cement. A blend of 10 percent cement by weight with the VRS waste will serve to bind a portion of the interstitial water in a chemical reaction with the cement. That water will then be eliminated as potential leachate. A review of the literature indicates that the cement consumes approximately 10 to 20 percent of its own weight in water in the process of hydration (Troxell and Davis 1956). A typical concrete mix contains much more water than the water needed for hydration; the additional water is necessary to make the mix workable.

Thus, 100 lbs of VRS waste at 20 percent moisture by weight contains 20 lbs of water. If 10 lbs of cement are added, the cement will consume at most 2 lbs of water. The resulting unbound moisture content would be 16 percent (18 lbs/110 lbs), which represents a reduction of 4 percent.

The cement could be mixed with the soils on the surface of the landfill by spreading the soil and cement in approximately the correct proportions over a working surface of 1 acre. The blending would be accomplished using graders and dozers. After blending the stabilized waste would be compacted in relatively thin (<12 in.) lifts.

This stabilization method is similar to dam construction using roller compacted concrete (RCC), which has enjoyed considerable attention over the last 15 years. A significant amount of technical information on the behavior of RCC embankments exists and could be used to evaluate the expected behavior of this stabilization method.

Soil Cement

Soil Cement has been in use for many years. It is commonly used for stabilization of road bases, sub-bases, earth dam cores, trenches, frost protection and reinforcement of load-bearing layers (Publications Committee of X.ICSMFE 1981).

The fundamentals of soil-cement stabilization involve thorough mixing of cement with soil and compacting it in thin layers (6 to 12 inch thick) using drum or sheeps foot roller compactors (Welsh 1987). There are three types of soil-cement (Fang 1990).

- Soil-Cement contains sufficient cement to be a hard and durable mass with only enough moisture to satisfy the hydration requirements of the cement and to provide sufficient lubrication for compaction of the mix to a high density.

- Cement-Modified Soil is an unhardened mixture of soil and cement, with a relatively small portion of cement added to silty clay soil which reduces the tendency for volume change and plasticity, and increases the load-bearing capacity of the soil.

- Plastic Soil-Cement results in a hardened product and is similar to plastering mortar when placed. It is comparable to soil-cement but is primarily used for surface protection against erosion control.

These methods will fill a portion of the voids in the soil with a cement paste which will also use and lock up some of the free water in the soil, which is desirable. The soil-cement will have an increased strength when compacted in place which will help reduce settlement and creep. The cementing will also reduce the permeability of the soil. The available free space in the soil will be reduced by the volume of the cement paste introduced, and may reduce the absorptive capacity of the soil.

Fly Ash

Fly ash is predominately an alumina and silica by-product of coal-fired power generation and is pozzolanic, meaning that it forms a cement in the presence of lime and moisture, by producing a stable calcium silicate (Troxell and Davis 1956). Class C ashes have sufficient lime in the ash to be self-cementing and will cause cementation without addition of lime (Welsh 1987). Other classifications require addition of limit be acceptable. Ten to 15 percent ash by weight has been used to stabilize dune sands (Welsh 1987). Intimate mixing is necessary for uniform results and may be difficult to achieve in the field. The initial set of fly ash mixtures can be quite rapid. Without use of retarding agents, compacting after initial set can result in a reduced strength, but still greater than compacted soil without fly ash. Ash stabilization requires more stringent quality control during construction than soil-cement to achieve similar uniform properties.

3.3.1.2 Lime. Lime has been widely used as a soil stabilization agent for many years. Typically quicklime (CaO) or hydrated lime ($Ca(OH)_2$) is added to clayey soils to improve their engineering properties for used as foundations (Hoddinott and Lamb 1990). The lime combines with the silica in the soil to produce a cementatious matrix, which is chemically similar to Portland cement. Lime is most often used to 1) dry a clayey soil, which allows improved compaction and the associated strength improvements, 2) reduce the plasticity of a clayey soil, 3) reduce the shrinkage and swell characteristics of the soil, and 4) improve the bearing capacity of a clayey soil through cementation. Typical application rates vary from 2 to 10 percent by weight of soil, generally in proportion to the clay content of the soil and the bearing loads which will be applied (Hoddinott and Lamb 1990).

In this alternative, lime would be blended with incoming waste on the working surface of the landfill at a rate of approximately 4 percent lime by weight. Mixing with the waste would be done by graders and compactors.

3.3.1.3 Absorbents. This alternative consists of adding a specialized absorbent to the soil to immobilize the interstitial water. The Hanford Site Solid Waste Disposal Criteria (Willis and Triner 1991) includes a list of approved absorbents. Of these, two which would be applicable are Solid-A-Sorb, which is a mineral diatomaceous earth, and WYK, which is an amorphous silicate. Absorbents which are shipped as granular particles (as opposed to sheets or rolls) would be placed on a working surface of the waste and blended using graders and dozers in a manner similar to other stabilizers. Application rates would vary depending on the type of absorbent selected. For WYK, the recommended rate is 1 lb of absorbent for each 2 lbs of water. Since the disposal criteria target is to remove water equivalent to 10 percent by weight of the waste, the absorbent would be added at a rate of 5 percent by weight. Compaction would be done in place, following blending. The low density of the absorbents would result in a 10-percent bulking of the waste.

3.4 BLENDING

3.4.1 Concept

Wet waste delivered to the ERSDF could be mixed with dry soils or dry waste. The resulting blend of soils would meet the design criteria for moisture content and strength. There are two options under this alternative: 1) blending with stockpiled from the ERSDF site, and, 2) blending with incoming ERSDF waste. In either case, the blending must be done with soils that meet certain requirements.

3.4.1.1 Blending Soil Requirements. In order to meet the moisture limits established in the waste disposal criteria (Section 2.3.5), the wet VRS waste must be thoroughly blended with a sufficient quantity of dry soil. All natural soil contains some moisture, and the moisture content of the blending soil has an influence on the quantity which must be added. The relationship between quantity and moisture content was evaluated and the results are presented graphically on Figure 3-3. As shown, a very dry blending soil with a water content of 2 percent requires a blending ratio of 1.25 parts soil to 1 part waste in order to meet the criteria of 10 percent water by weight. As the blending soil becomes wetter, much more is needed: with soil at 6 percent moisture, a blending ratio of approximately 2.5 parts soil to 1 part waste is required to meet the criteria.

The grain-size distribution of the waste is also a consideration for blending. While the values presented in Figure 3-3 show the general relationship of moisture content and blending volumes, the grain size distribution of the blending soil has an influence on the field capacity of the mixture as well. The VRS waste will be sandy silt and the blending soil must be similar if the resulting mixture is to produce an increase in the water absorption capacity. Although there is no available testing data for support, it seems intuitive that a blend of VRS silt with relatively clean dry gravel would reduce the water content, but would do little to increase the water absorption capacity. An increase in the water absorption capacity results from the creation of many dry interstitial voids between the soil particles. The addition of gravel to a silt is not likely to produce many interstitial voids, at least not in the same way that adding a dry fine sand or silt would. This concept should be considered in the development of a blending alternative.

3.4.1.2 Blending with Waste. Blending with waste would be done by combining the main ERSDF trenches with the VRS disposal facility. VRS waste would be spread in areas where most of the ERSDF waste is soil and not drums or other solids. The VRS waste would be spread in lifts approximately 3 inches thick. The waste would then be blended with the underlying and dryer ERSDF waste using dozers and/or graders. The ERSDF waste is expected to have a moisture content similar to typical Hanford soils, which is approximately 4 percent by weight. The graph on Figure 3.3 shows that a blending ratio of approximately 1.6 parts ERSDF waste to 1 part VRS waste would be sufficient to meet the moisture criteria, if the field capacity of the blended waste is similar to the VRS waste alone. With a lift thickness of 3 inches, it should be possible to blend to a ratio as high as 3:1 without difficulty.

As discussed in the preceding section, the benefit to long-term groundwater protection provided by blending VRS waste with ERSDF waste is dependent on the resulting change in moisture absorption capacity. Existing data is not adequate to resolve this issue; laboratory testing on representative samples of waste is required in order to determine the potential benefit.

To blend these wastes, the main ERSDF facility must be in operation simultaneously with the VRS facility such that there is dry waste with which to blend. Assuming the main ERSDF facility is not in operation for one day, the VRS waste would cover 1.3 acres with a lift 3 inches thick, at the maximum production rate of 540 CY/day.

3.4.1.3 Blending with Uncontaminated On-Site Soils. This alternative consists of blending wet VRS waste with uncontaminated on-site soils. In order to construct the VRS waste disposal landfill, a large excavation would be required, resulting in large stockpiles of fine grained soils adjacent to the landfill. This soil, which is relatively dry (approximately 4 percent moisture by weight), would be blended with wet VRS waste in quantities necessary to meet the criteria. Blending would be done by alternate placement of loads of waste and soil on a working surface, followed by mixing using graders and compactors.

A second placement method would involve staged construction of the landfill. Landfill construction would begin at one end of what would eventually become a long trench. Waste placed in this initial cell would be mixed with soil being excavated for construction of the adjacent landfill cell. This approach would reduce the cost of handling materials.

Because blending with on-site soils increases the total volume of waste, the landfill airspace requirements would increase. Assuming a blending ratio of 1.6 to 1, the required air space for this alternative would be 1,950,000 CY.

3.5 EVAPORATION ENHANCEMENT

3.5.1 General

The Hanford climate, with its low rainfall, low humidity and abundant sunshine, provides an opportunity to reduce the water content of wastes through evaporation. This altered consists of spreading wet VRS wastes in thin layers and allowing them to dry to the required water contents.

3.5.2 Evaporation Potential

The evaporation potential from bare soil surfaces was estimated using the EPA's Hydrologic Evaluation of Landfill Performance (HELP) computer model (Schroeder et al. 1989), together with meteorological data appropriate for the Hanford site. In order to evaluate the maximum potential evapotranspiration (ET) from the soil surface, the HELP program, which evaluates environmental conditions, must be "tricked" into performing the correct simulation. Actual ET at the Hanford site is much lower than the potential ET because the available soil moisture is restricted due to the very low precipitation which occurs. The precipitation data was altered to be 0.5 inches per day, everyday for five years. This high precipitation maintains a high water content in the surface soils and simulates wet VRS waste which would constantly be mixed and then replaced after drying. The soil surface was assumed to be free of vegetation; thus, a leaf area index (LAI) of 0 was assigned. The HELP model results are shown graphically on Figure 3-4. It is clear from the figure that there is a major variation in average potential ET from summer to winter. While summer months provide approximately 0.33 inches/day ET, the winter ET is only .01 inches/day. Since these are gross (not net) values, site precipitation may produce a net negative ET during significant portions of the winter. Precipitation averages approximately 0.02 inches/day.

The HELP model results suggest that a system which relies on atmospheric and solar evaporation must be conducted on a seasonal basis. The average annual maximum potential ET is approximately 0.15 inches/day; the effective maximum potential ET is a 0.13 inches/day because of precipitation. However, nearly all of this ET occurs during the summer months, from May through October. During this period the net potential ET is approximately 0.31

inches/day. For design purposes, a lower value of effective summer ET should be used, because the value must be an average over a full 6-month period, not just July. In addition, the drying of the VRS waste will reduce actual ET below the maximum potential levels. For these reasons, a design net ET rate of 0.20 inches/day was assumed for the summer months. The net winter ET rate was assumed to be zero. These values should conservative, because the HELP model does not account for wind, which is expected to significantly enhance evaporation from exposed soil.

3.5.3 Atmospheric Drying

This alternative consists of spreading thin lifts of wet VRS waste over a large area until it is sufficiently dry to meet the criteria. The waste would be periodically turned using a harrow or similar implement to bring wetter materials to the surface and expose them. Following drying, the waste would be compacted in place and a new batch of wet waste would be placed. Because winter ET is zero, winter waste production would have to be stockpiled in the landfill and dried the following summer.

The size and scope of this alternative was estimated by laying out a landfill which meets the criteria. A plan and section of such a landfill are shown on Figure 3-2. In this design, one end of the landfill is dedicated to the stockpile for winter waste production. The maximum annual total volume would be approximately 30,000 CY uncompacted. This stockpile is shown on Figure 3-2. The remaining landfill floor must be large enough to dry the peak waste production rate of 540 CY/day plus an additional 270 CY/day from the stockpile. Assuming wet VRS waste is placed in a lift 6-inches thick (final thickness after compaction to 100 pcf dry density), the water which must be evaporated to achieve the criteria has an equivalent depth of 1.2 inches. At the design evaporation rate of 0.2 inches/day, the lift must remain exposed with periodic mixing for a period of 6 days. The peak waste production rate is 810 CY/day, which will occupy an area of approximately 1 acre when it is spread in a 6-inch (compacted) lift. The actual lift thickness during the evaporation process would be closer to 12 inches because of bulking of the waste caused by the plowing and harrowing being done to keep wet waste at the surface. The layout shown on Figure 3-2 provides eight cells on the floor of the landfill; each cell has a area of 1 acre, and represents one day of waste production at 810 CY/day. Six of the cells are in an evaporation stage at any one time; one cell is being compacted and one cell is receiving waste. The activity in each cell will rotate daily.

The sizing of the facility shown in Figure 3-2 is determined by the area of the floor in the first year of operation. It is assumed that the facility must have enough volume to contain the stockpiled winter production while providing 8 acres of floor area for evaporation, placement and compaction. The working area will become larger each year as the surface of the waste rises above the floor. Alternative cell arrangements would be possible in subsequent years of operation.

3.5.4 Solar Greenhouse

This alternative involves the construction of a large moveable greenhouse over the disposal area, which would enhance the evaporation rates. The structure would need to be large enough to allow placement and mixing of the materials within the enclosure. The greenhouse alternative was considered because it might eliminate the winter stockpile, and it might make it possible to stage the landfill construction.

Even with the elimination of a winter stockpile and with the enhanced evaporation rates, the greenhouse area required would be approximately 4 acres (420 ft x 420 ft). To accommodate the heavy equipment operating inside, the structure would need to have a clear span. Such a structure, if it is square, would likely be air-supported. Alteratively, the structure could be a long thin rigid frame. Special air-locks and foundation details would be required to prevent air leakage from around the moveable foundation. Movement of such a structure from one location to another is unprecedented. High winds could threaten the integrity of the roof. Clear roof fabric would likely deteriorate rapidly from UV exposure and require frequent replacement.

Because the benefits of the solar greenhouse are considered modest, involving the scheduling of expenditures rather than the total cost, and because the associated design problems are likely to be formidable, this alterative was dropped from further consideration.

3.6 MODIFICATION OF EQUIPMENT OR PROCEDURES AT OPERABLE UNIT TREATMENT FACILITY

This alternative involves modifying the VRS soil washing and dewatering equipment at the operable unit so that the VRS waste does not require special handling when it reaches the ERSDF. The proposed equipment modifications include additional dewatering through thermal drying or other methods, and addition of chemicals or absorbents.

3.6.1 Additional Mechanical or Thermal Drying

The first step in dewatering the pumpable VRS waste from the thickener will involve dewatering equipment. There are three main types of equipment for dewatering slurry to produce solid cake: rotary vacuum filters or drums, belt filter presses, and recessed-plate filter presses. A review of the literature indicates that vacuum filters and belt filter presses have similar performance, with the belt press slightly better. Vacuum drum dewatering has historically been the most widely used (e.g., in municipal wastewater treatment), but belt filter presses are gaining predominance. Recessed-plate filter presses generate the lowest water content. For comparison, belt filter presses achieve 70 percent water by weight on a wastewater sludge, whereas a recessed-plate filter presses achieve 50 percent water. Waste water sludges have higher water contents than VRS waste; however, the effectiveness of the equipment would be similar. Recessed-plate filter presses operate in batch mode and have significantly higher operating and maintenance costs than the others. Recessed-plate filter presses are labor-intensive and the cost of filter cloth replacement is high. Recessed-plate filter presses are generally not suitable for high production rates. Because of these considerations, a belt filter press is likely to be the best choice for VRS waste.

The solids cake from dewatering equipment will have a moisture content above the field capacity of the soil, regardless of dewatering equipment used. In order to remove additional water and achieve a moisture content below the field capacity, the soil cake must be dried using thermal treatment. Air drying is often used for his step, especially in the wastewater sludge industry. However, this alternative assumes that thermal drying must be done using equipment. Many types of dryers are available: direct heat or indirect heat (e.g. steam), rotary drums, moving-belts and trays, vacuum-assisted (i.e., vacuum with heat) and others. Selection of a specific type of dryer will require additional information on the characteristics of the filter cake and additional vendor information on the equipment. For purposes of comparison, a heated hollow-flight auger or heated conveyor was selected as the drying equipment. The cost estimates presented in Section 4.3 are based on this type of equipment, using electrical energy for drying.

3.6.2 Chemical Additives at the Operable Unit

Any of the chemical additives which were proposed for addition to the VRS waste within the landfill, as described in Section 3.3, can also be added to the waste at the VRS facility as part of the dewatering treatment. These include cement lime, absorbents, and fly ash. While mixing waste with such materials would be theoretically possible using a pug mill or other mechanical device, there is no apparent benefit, and several increased costs. The capital cost of the pug mill would not be balanced by a significant reduction of cost at the landfill since dozers and graders are required to spread the waste even which it arrives at the landfill blended with additives. All of the additives would consume space in the containers, increasing transportation costs.

Since this alternative has no apparent benefit over the chemical additive alternatives discussed in Section 3.3, while having several additional costs, this alternative was dropped from further consideration.

3.7 MECHANICAL DEWATERING AND/OR STABILIZATION SYSTEMS

There are two general conditions addressed under this alternative: 1) dewatering of the occasional container that has waste with a very high water content and which cannot be placed in the landfill even for blending or stabilization without initial dewatering; and, 2) tertiary dewatering of the entire waste stream, using stationary equipment located at the ERSDF, to a water content which will allow the waste to be disposed in the landfill without any further treatment. Primary dewatering using thickeners and secondary dewatering using a belt filter press (or similar method) will be done at the OU as part of the soil washing process.

3.7.1 Small Batch Dewatering

The dewatering of small quantities of VRS waste could be done using mechanical equipment as described in Section 3.6.1. The size of the equipment would be matched to the design rate. A recessed plate filter press might be the preferred alternative for small batches of waste.

An attractive alternative to the installation of mechanical equipment would be the enforcement of a waste acceptance criterion, which would require waste with excessive moisture to be sent back to the Operable Unit for reprocessing prior to acceptance for ERSDF disposal. Clearly this would be the simplest alternative for solving a situation that is essentially a quality control problem in the site remediation and VRS dewatering process.

3.7.2 Tertiary Mechanical Dewatering Procedures

This alternative is essentially the same as that discussed under 3.6.1, except that the equipment is located at the ERSDF site, rather than being part of the soil washing system. As described previously, dewatering of waste beyond its field capacity will require thermal drying. It is assumed that a heated hollow-flight auger or heated conveyor will be used for this purpose.

4.0 COMPARISON OF ALTERNATIVES

4.1 TECHNICAL PERFORMANCE

4.1.1 Existing Treatment Facilities

4.1.1.1 Disposal Criteria. Addition of absorbents to the waste, followed by containerization of the waste, are expected to meet the disposal criteria. The absorbent/waste mixture in the landfill would have adequate water absorption capacity, and settlement within the landfill could be maintained at less than the 3 percent limit.

4.1.1.2 Operational Criteria. Since the waste is containerized, this alternative would meet radiological emissions standards in the case where the space around the waste containers is backfilled with clean soil. If this space is backfilled with waste, this alternative has the same radiological emissions problems that are present for the entire ERSDF. In either case, non-radioactive dust emissions problems may exist. Fine-grained on-site soil backfill may produce more dust emissions than the coarser-grained ERSDF waste.

4.1.2 Chemical Additive Treatments

4.1.2.1 Disposal Criteria.

Cement

The addition of 10-percent cement by weight will provide significant increases in the waste's strength and resistance to settlement. The permeability may decrease slightly. However, none of these characteristics are a problem with simple compaction of the waste by itself. With respect to the change in water absorption capacity, it is not clear what effect cement will have. While it will result in a reduction in the water content of the total waste of approximately 4 percent, the field capacity may also be affected. It is not clear whether the affects will be positive, negative, or zero. Since the field capacity may have changed as a result of the addition of cement, it is also possible that the net effect of the addition of cement may be to decrease the water absorption capacity of the waste. Additional review of the literature, especially the RCC dam materials testing, may provide better information on the performance and characteristics of soil-cement blends.

Cement may bind radionuclides to the larger soil particles, and thus reduce the potential for their migration out of the landfill. However, the low cement content and incomplete mixing expected may reduce these benefits. In addition, if radionuclide migration is controlled by diffusion, the presence of grout may not significantly reduce transport rates. For these reasons, no credit was taken for improved long-term performance from mixing with cement.

Lime

Lime stabilization is not the primary type of stabilization which is needed in the VRS waste. There is some direct consumption of water through chemical activity; however, it is not clear how much is consumed. Following the addition of lime, soils show a substantial drop in clay content due to the agglomeration of the clay particles in the presence of the lime. This agglomeration process is likely to reduce the field capacity of the waste since the sandy silty materials tend to have a lower field capacity than clayey materials. To the extent that the field capacity is reduced more than moisture is consumed, lime may reduce the absorption capacity of the waste blend. The net change in water absorption capacity cannot be estimated without test data.

Absorbents

According to manufacturers' literature, the absorbents will bind water and will prevent it from being leached. If true, the absorbents would meet the criteria for water absorption capacity at an application rate of 5 percent. Because the density of amorphous silicate is only 50 pcf, there will be a volume increase which is greater than 5 percent, probably in the range of 10 percent. The settlement and strength characteristics of the blend is not known, but it is expected to meet disposal criteria requirements.

4.1.2.2 Operational Criteria.

Cement

Addition of fine cement at the landfill could present a dust problem because of the fine grind of cement. The use of a pug mill for blending would eliminate dust emissions during blending. Once the cement is blended, the potential for dust emissions will likely be very low because of the binding properties of the cement.

Lime

Like cement, the addition of lime at the landfill could present a dust problem if the lime is a fine powder. This could be eliminated using a coarse granular lime. Also, the use of a pug mill for blending would eliminate dust emissions during blending. Once the blended lime sets and becomes cementatious, the potential for dust emissions will likely be very low.

Absorbents

Absorbents are expected to dry the soil to some degree but not completely. The residual moisture in the soil should be enough to prevent dust emissions most of the time. Occasionally the surface of the fill may become dry, and dust could become a problem.

4.1.3 Blending

4.1.3.1 Disposal Criteria. The disposal criteria for strength and settlement would be met for all blending alternatives. The success in meeting the criteria for water absorption capacity depends on the materials being blended. If on-site soils are used from the stockpiles, the absorption criteria will almost certainly be satisfied. Nearly all on-site soils are fine grained soils composed of fine sand and silt. ERSDF waste will likely have a wide range of grain sizes: from well sorted very gravelly materials to well graded blends which include silts and clays, see Figure 2-1. If gravelly ERSDF waste is used as the blending material, there may be a reduction in field capacity along with a reduction in moisture content. The net effect may be only a very slight increase in moisture absorption capacity over the original wet waste. Soils testing is required in order to accurately evaluate the effects of the various blending material types and sources.

4.1.3.2 Operational Criteria. Dust emissions from blending operations will be moderate. Dust suppression may be necessary to reduce emissions. If on-site soils are used as a source of blending materials, the total volume of the landfill will be larger than that required using ERSDF waste by a factor of 2 to 3. There will be a correspondingly larger risk of dust emissions, although the radiological component is not likely to be larger.

4.1.4 Evaporation Enhancement

4.1.4.1 Disposal Criteria. Evaporation enhancement using atmospheric drying will achieve the disposal objectives.

4.1.4.2 Operational Criteria. Dust emissions are expected to be greater than other alternatives because the area of exposed waste will be 10 to 15 acres. While the material at the surface will be wet much of the time, weekends and windy periods will require the use of dust suppression. Stockpiled areas will be receiving new wet waste 5 days per week. On weekends, dust suppression covers will be required.

4.1.5 Modification of Procedures at Operable Unit Treatment Facility

4.1.5.1 Disposal Criteria. If the VRS waste is dried at the operable unit as part of the soil washing and dewatering process, the waste will be delivered to the landfill and placed at a moisture content which will meet the water absorption criteria. Modest compactive effort will achieve the settlement and strength requirements.

4.1.5.2 Operational Criteria. This method of placement would allow a relatively small, phased landfill. The waste will be moist when placed. For these reasons, dust emissions from the fill would not be as large as other alternatives.

4.1.6 Mechanical Dewatering and/or Stabilization Systems

4.1.6.1 Disposal Criteria. A small batch-type mechanical dewatering system for occasional extremely wet waste would be designed to meet criteria for incoming normal VRS waste. The disposal performance would depend on the associated disposal method being used.

For the case of a thermal drying unit installed at the VRS landfill to dewater the entire waste stream, waste would be placed at a moisture content which will meet the water absorption criteria. Modest compactive effort will achieve the settlement and strength requirements.

4.1.6.2 Operational Criteria. This method of dewatering would allow a relatively small, phased landfill. Waste will be placed on a relatively small active fill surface. For these reasons, dust emissions from the fill would not be as large as other alternatives. A major disadvantage includes the need to decontaminate the equipment in order to perform maintenance.

4.2 SCHEDULE AND QUANTITY IMPLICATIONS

4.2.1 Existing Treatment Facilities

Because this alternative produces packaged waste, the associated landfill for disposal can be constructed in stages (phased). This will realize some savings over other landfills which require full development initially. The packaging of the waste with a stabilizer will increase the total volume. The stabilizer is expected to add 5 percent and the packaging 5 percent. If the space around containers is backfilled with ERSDF waste, there are no further inefficiencies. However, if the space is backfilled with uncontaminated soil, the required landfill airspace will increase by approximately 30 percent.

4.2.2 Chemical Additive Treatments

The addition of cement, lime or absorbents to the waste will allow a phased landfill construction. The total volume increase will be less than 10 percent in all cases.

4.2.3 Blending

The nature of the blending operations would allow phased landfill construction. If the blending soil is ERSDF waste, the net volume expansion would be zero. In contrast, the use of local soil for blending will produce a 100 to 250 percent increase in the waste volume requiring disposal.

The use of ERSDF waste for blending could present scheduling problems. Some ERSDF waste is likely to be unsuitable for blending because of its gravel content. If this is the only waste available for blending, or if no waste is available for blending, the VRS waste must be stockpiled or local soils must be use for blending. Stockpiling leads to expensive double handling of the materials, while blending with the local soils will increase the total landfill volume requirement.

4.2.4 Evaporation Enhancement

Because evaporation requires a large working area and the minimum landfill area occurs immediately after construction, the alternative using evaporation must be constructed to its full dimensions immediately. The area needed is approximately 10 acres, which is approximately the area needed for a completed landfill. If the total landfill volume was much greater but the delivery rate remained the same, the landfill construction could be phased. However, the total waste volumes and waste delivery rates specified in the FDC (Moore 1993) indicate construction in one phase.

4.2.5 Modification of Procedures at Operable Unit Treatment Facility

This alternative would allow phased construction of the landfill. Since the waste is thermally dried, there would be no increase in the volume of waste.

4.2.6 Mechanical Dewatering and/or Stabilization Systems

This alternative would allow phased construction of the landfill. Since the waste is mechanically dewatered, there would be no increase in the volume of waste.

4.3 COST

4.3.1 General Approach

The cost of each of the waste disposal alternatives was estimated at a conceptual level using estimates of the quantities involved and very approximate unit prices and lump sum cost estimates. The cost estimates are summarized on Table 3. The detailed calculations and assumptions used in the development of the cost estimate are presented in Appendix A.

The cost estimates reflect the area of liner involved, excavation to prepare the landfill, and the savings that could be realized by phasing the construction. When landfill construction is phased, it has been assumed, based on engineering judgement, that 27 percent of the construction cost will occur in the first year, and 10 percent in the last year. During the remaining operating years, the construction cost was assumed to be 7 percent per year. At an annual interest rate of 5 percent, the present value of such a cost stream is approximately 83 percent of the sum of the costs.

The cost estimates include a component for equipment. This item is intended to cover the dozers, graders, compactors, and other construction machinery necessary to spread and compact the waste in the landfill. In addition, any specialized mechanical equipment such as thermal dryers or waste packaging machinery are also included in this item.

Each cost estimate includes an operation and maintenance component. These costs vary significantly among the different alternatives and reflect the variations in energy costs, labor costs and equipment maintenance.

The last column of Table 3 shows the unit cost of waste disposal. This is the present value of the capital cost divided by 750,000 CY, plus the annual operations and maintenance (O&M) cost divided by 75,000 CY. Although the cost estimating methods are very approximate, the resulting unit costs provide a means for comparison of alternatives.

4.3.2 Existing Treatment Facilities

The capital cost of these facilities is dominated by the mechanical equipment necessary to stabilize and containerize the waste at the design rate. This equipment must add absorbent to the waste stream, mix the combination, and place it in drums. The drums must

Table 3. Cost Comparison of Alternatives.

	Quantity Factor	Landfill Efficiency	Liner Area (1) (sq ft)	Phase Factor	Present Worth Landfill Cost (3)	Equipment Cost	Total Disposal Capital Cost	Annual Operating Cost	Unit Disposal Cost (4)
ALTERNATIVE									
Expansion of Existing Treatment Facilities	1.10	0.85	970,588	0.83	$8,206,000	$5,000,000	$13,206,000	$14,447,000	$210
Chemical Additive Treatments									
Cement	1.10	0.85	970,588	0.83	$8,206,000	$620,000	$8,826,000	$1,300,000	$29
Lime	1.04	0.85	917,647	0.83	$7,759,000	$620,000	$8,379,000	$1,150,000	$27
Absorbents	1.10	0.85	970,588	0.83	$8,206,000	$620,000	$8,826,000	$4,000,000	$68
Blending									
with ERSDF Waste	1.00	0.85	882,353	0.83	$7,460,000	$350,000	$7,810,000	$500,000	$17
with On-Site Soils	2.60	1.30	1,500,000	0.83	$13,801,000	$850,000	$14,652,000	$1,100,000	$34
Evaporation Enhancement	1.00	0.85	882,353	1.00	$9,000,000	$600,000	$9,600,000	$700,000	$22
Modifications at the Operable Unit (2)	1.00	0.85	882,353	0.83	$7,460,000	$3,700,000	11,160,000	$1,200,000	$31
Mechanical Dewatering (2)	1.00	0.85	882,353	0.83	$7,460,000	$3,700,000	$11,160,000	$1,200,000	$31

Notes:
(1) Actual slope area, not horizontal projection
(2) Assumes thermal drying
(3) Unit cost for Excavation = $2 per CY
Unit cost for Liner = $8.50/sq ft
(4) Annual Interest Rate = 5%

be sealed and placed in the landfill. The system must be capable of doing this at the rate of 2.5 drums per minute. The O&M estimate includes the cost for drums at $22 each, and the cost of absorbent at $0.25 per lb of water absorbed.

4.3.3 Chemical Additive Treatments

Alternatives involving the blending of cement or lime with the VRS waste result in relatively modest unit costs for waste disposal. The estimated costs include the cost of cement and lime at approximately $5/CY of waste.

4.3.4 Blending

The alternatives involving blending of the VRS waste with ERSDF waste appear to produce the lowest unit costs for disposal. The low cost results from the efficient use of the landfill airspace, and the relatively simple equipment and O&M requirements. When on-site soils are used for blending, the total volume of landfill airspace required increases to 250 percent of the VRS waste volume. Although there are some economies of scale, the cost per unit volume of original waste is substantially higher.

4.3.5 Evaporation Enhancement

The unit disposal cost for enhanced evaporation is low relative to the other disposal methods. The unit cost is similar to blending with ERSDF waste, except that the landfill construction cannot be phased and O&M costs are somewhat higher due to the labor and equipment necessary to stockpile winter waste and to periodically turn the surface of the waste to enhance evaporation.

4.3.6 Modification of Procedures at Operable Unit Treatment Facility

The addition of a thermal dryer to the soil washing and dewatering equipment will increase the capital costs by a substantial amount. However, the required energy for drying is also significant. The O&M cost for this alternative is very sensitive to water content and energy prices and the O&M cost has a major effect on the overall cost. The combination of capital and O&M costs results in a unit disposal cost which is among the highest, although it remains reasonable for the assumed water contents and energy prices.

4.3.7 Mechanical Dewatering and/or Stabilization Systems

This alternative also involves thermal drying, which results in a correspondingly high unit disposal cost.

4.4 COMPARISON SUMMARY

A summary of the performance of the alternatives with respect to technical issues, schedule, size, and cost is presented on Table 4.

4.4.1 Technical Performance Summary

With few exceptions, all of the alternatives are expected to achieve the disposal criteria. The performance of waste blended with cement, lime, or gravelly ERSDF waste cannot be accurately predicted with respect to water absorption capacity without testing. These blends may not achieve the disposal criteria. If this deficiency exists, leachate may be generated sooner from landfills filled using these approaches.

Settlement and strength criteria are met by all the alternative methods of disposal.

Dust emissions are expected to differ among alternatives. Alternatives which require blending with on-site soils or which use atmospheric evaporation for dewatering will require large exposed areas of waste. Windy conditions which arise suddenly would make it difficult to apply dust suppressants rapidly and effectively over these large areas. Alternatives which use a binding agent mixed mechanically such as lime or cement will be inherently low in dust emissions because the landfill exposed areas are small and the waste is made cohesive and non-erodible by the binding agents.

4.4.2 Schedule and Quantity Summary

With two exceptions, the alternative disposal methods do not present scheduling problems. The landfill can be developed in phases over the life of the project as needed to meet the schedule for waste generation. The two exceptions are enhanced evaporation and blending with ERSDF waste. Enhanced evaporation does not permit a phased approach because the area requirements are relatively large at the beginning of operations. Blending of the VRS waste with ERSDF waste requires that the two waste streams be matched in terms of quantity and quality for the life of the landfill. It is not clear whether this scheduling is feasible.

4.4.3 Cost Comparison Summary

The cost estimate presented on Table 3 shows that expansion of the existing treatment facilities is very expensive. Alternatives which use absorbents are also relatively expensive. The lowest cost alternative consists of blending with ERSDF waste, because this involves the least amount of equipment and there is no cost associated with an increase in the volume of the waste or the need for admixtures. This is followed by enhanced evaporation and blending with cement or lime.

Table 4. Summary of Alternative Comparisons

ALTERNATIVE	DISPOSAL CRITERIA			OPERATIONAL CRITERIA	SCHEDULE	QUANTITY[2]	COST $/CY
	Settlement	Strength	Absorption	Dust Emissions			
Expansion of Existing Treatment Facilities	OK	OK	OK	OK	Phased	1.1[6]	$210
Chemical Additive Treatments							
Cement	Excellent	OK	Poor - OK[4]	OK	Phased	1.1	$29
Lime	Excellent	OK	Poor - OK[4]	OK	Phased	1.1	$27
Absorbents	OK	OK	OK	OK	Phased	1.1	$68
Blending							
with ERSDF Waste	OK	OK	Poor to Excellent Depending on the nature of the waste	OK	Possible problems scheduling waste generation	1.0	$17
with On-Site Soils	OK	OK	Excellent	OK	Phased	2.0-3.0[3]	$34[5]
Evaporation Enhancement	OK	Ok	Excellent	OK	Not Phased	1.0	$22
Modifications at the Operable Unit [1]	OK	OK	Excellent	OK	Phased	1.0	$31
Mechanical Dewatering[1]	OK	OK	Excellent	OK	Phased	1.0	$31

Notes:
(1) Thermal Drying is assumed
(2) Ratio of the required volume of the landfill to the total volume of the VRS waste (750,000 CY).
(3) Depends on the moisture content of available soils.
(4) Performance is not known; testing required.
(5) Assumes quantity ratio of 2.5.
(6) Assumes containers are backfilled with ERSDF waste.

5.0 RECOMMENDED ALTERNATIVE

This study shows that blending the VRS waste with ERSDF waste is the preferred alternative. This alternative allows phased development, and has no special equipment requirements. The concept is also applicable to waste which is wetter than the design value assumed for this study. There is no bulking of the waste due to the addition of non-waste materials. The performance of the blended waste should meet disposal criteria, if the ERSDF waste has the needed characteristics. The uncertainty regarding the feasibility of this method involves both the characteristics of the ERSDF waste stream and the schedule for generation of that waste stream. The ERSDF waste should be sufficiently fine-grained such that, when blended with the VRS waste, the combined waste retains a significant water absorption capacity. Further, ERSDF waste meeting the grain-size criteria should be generated at the same time as the VRS waste. These two aspects of the ERSDF waste stream should be investigated in more detail. Because the water absorption performance of the blended waste is critical to enhanced long-term groundwater protection, further design work advancing this alternative should include the necessary laboratory testing to evaluate the water absorption characteristics of the VRS waste alone as well as the VRS waste blended with coarse-grained ERSDF waste.

If blending with ERSDF waste is not feasible, blending with cement or blending with on-site soils appear to be the next best alternatives. Enhanced evaporation is also a viable alternative if the problem of dust emissions can be resolved. A number of dust suppressing agents are available, but performance is highly site-specific. The optimum materials, application techniques, and application rates should be determined by field testing.

More complicated alternatives involving mechanical or thermal dewatering can be cost competitive under certain conditions. However, because of the need to handle the waste twice or more, the large volumes involved, and radiation safety concerns during operations and maintenance, these alternatives are considered less desirable.

An additional alternative could be formulated from some combination of the attractive alternatives. For example, VRS waste might be blended with ERSDF waste as a primary option. When ERSDF waste is not available, or is of poor quality, the VRS waste could be blended with on-site soils or cement. During the summer, VRS waste could be dried by evaporation in a large ERSDF landfill. In practice, such a hierarchy of methods may be useful to ensure continuous capability for disposal of VRS waste while minimizing costs.

6.0 REFERENCES

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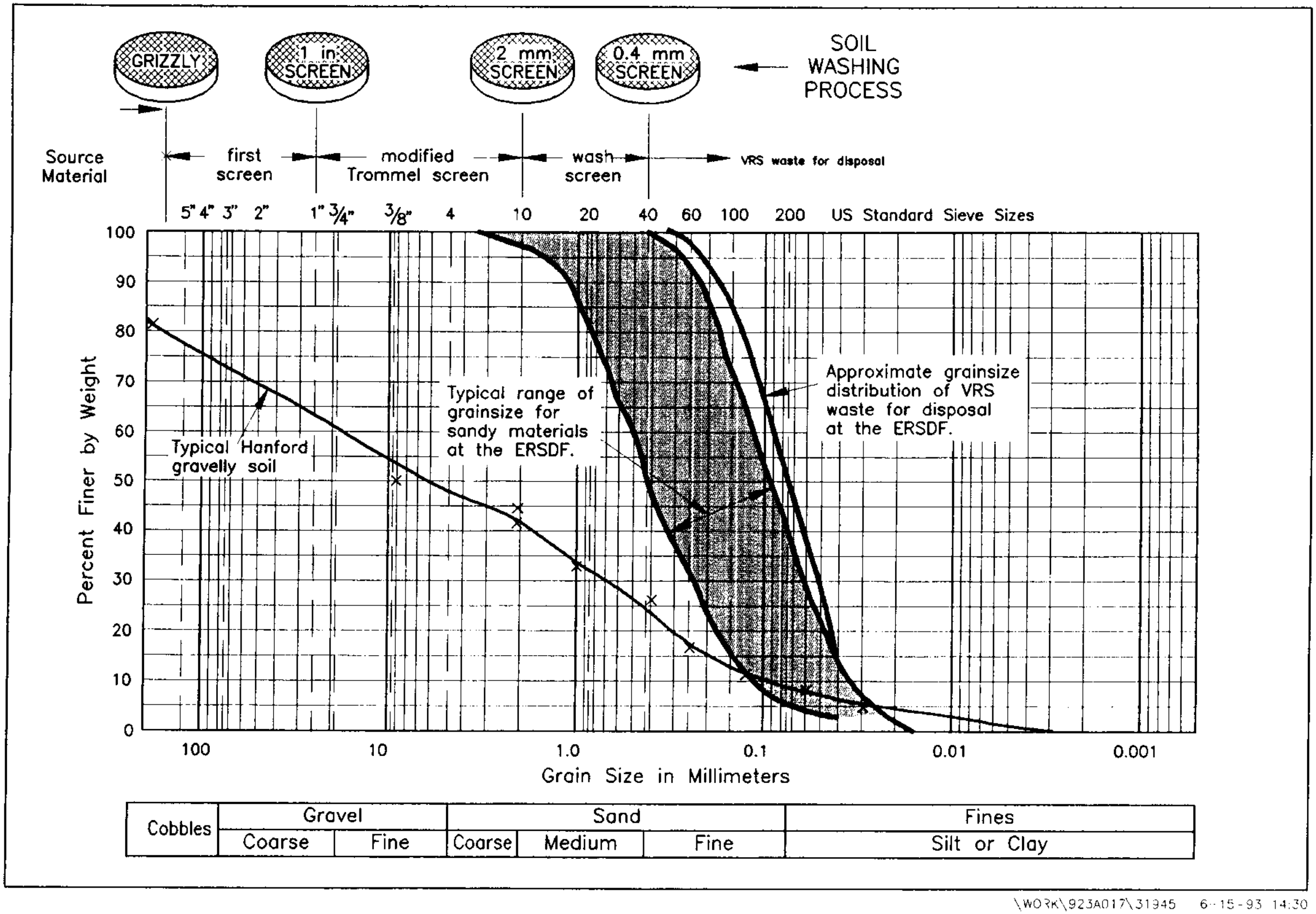

Figure 2-1. Grainsize Distribution of Waste Stream from VRS Soil Washing.

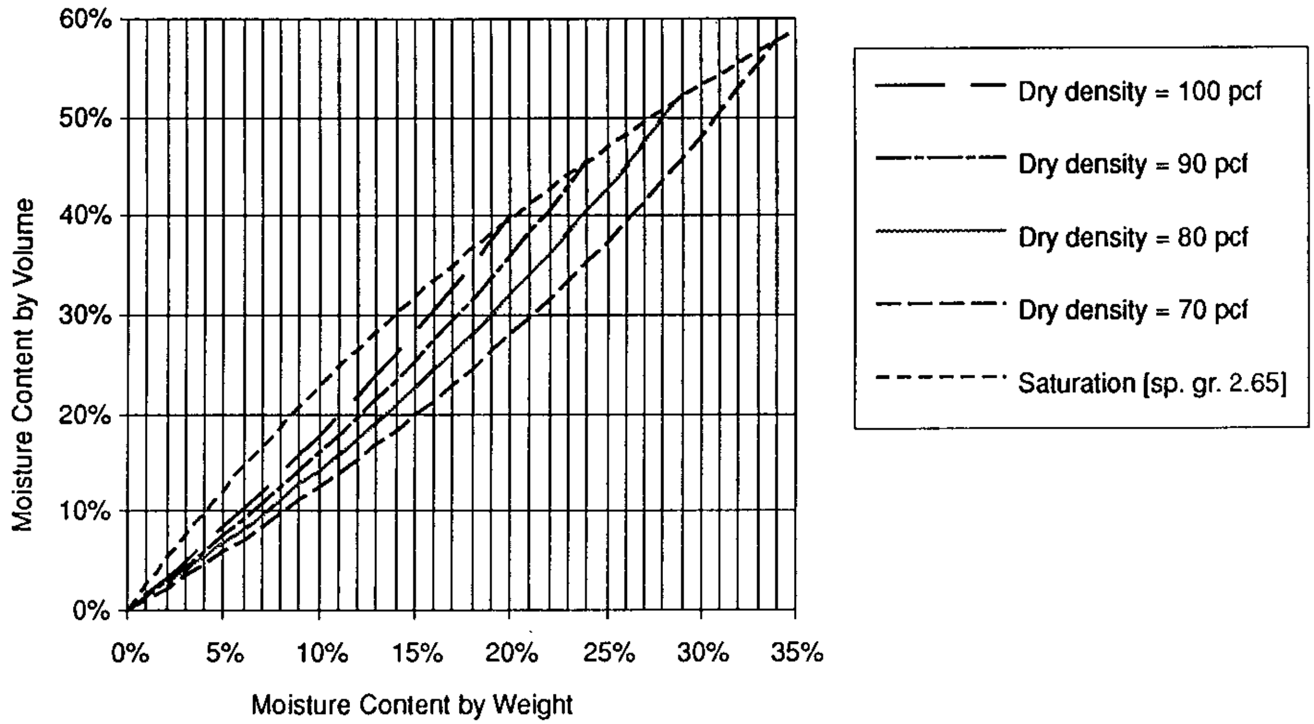

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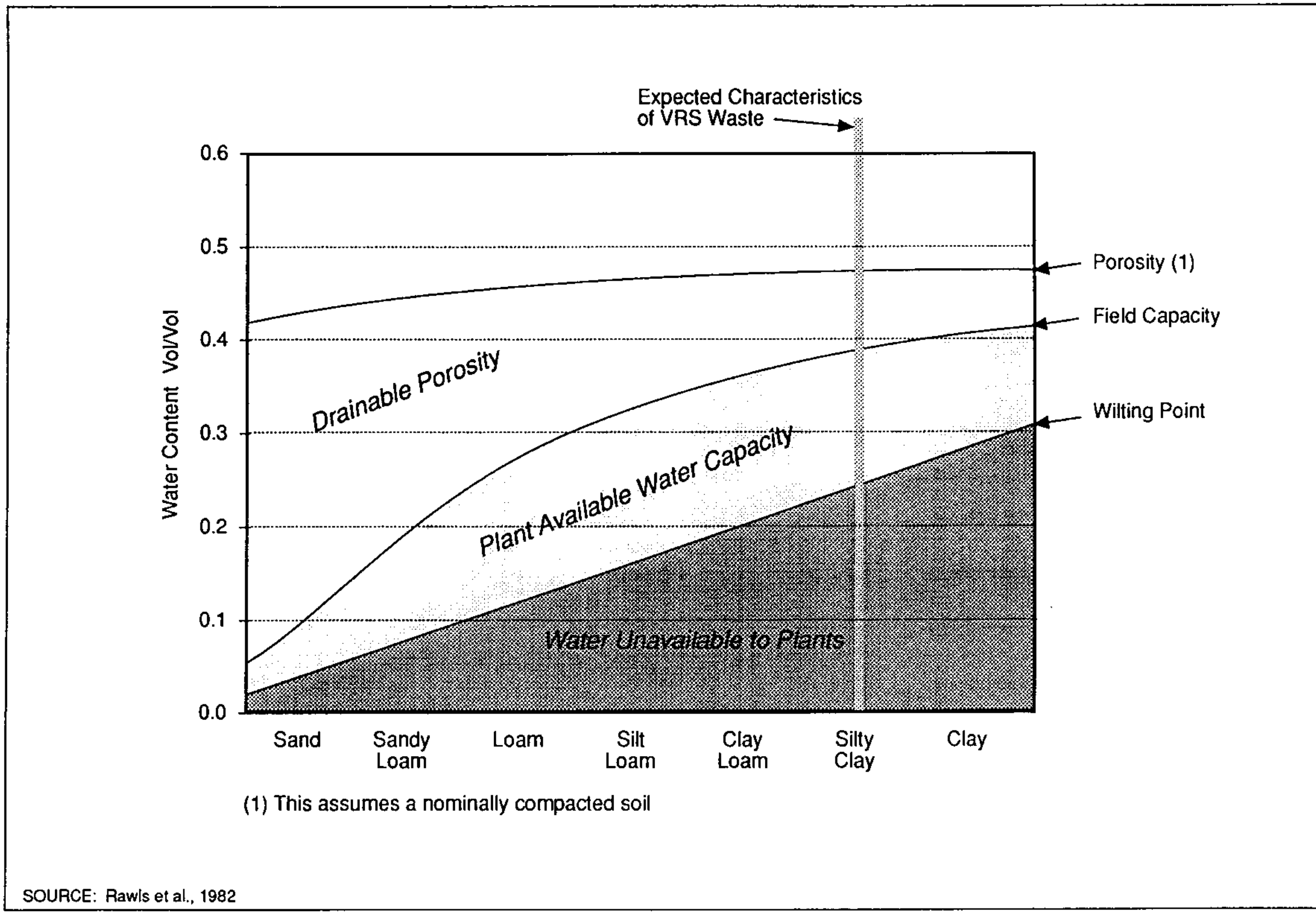
Figure 2-2. Moisture Content Variation with Dry Density.



923 A017/41177/7-23-93

Figure 2-3. General Relation Between Soil Water Properties and Soil Texture.

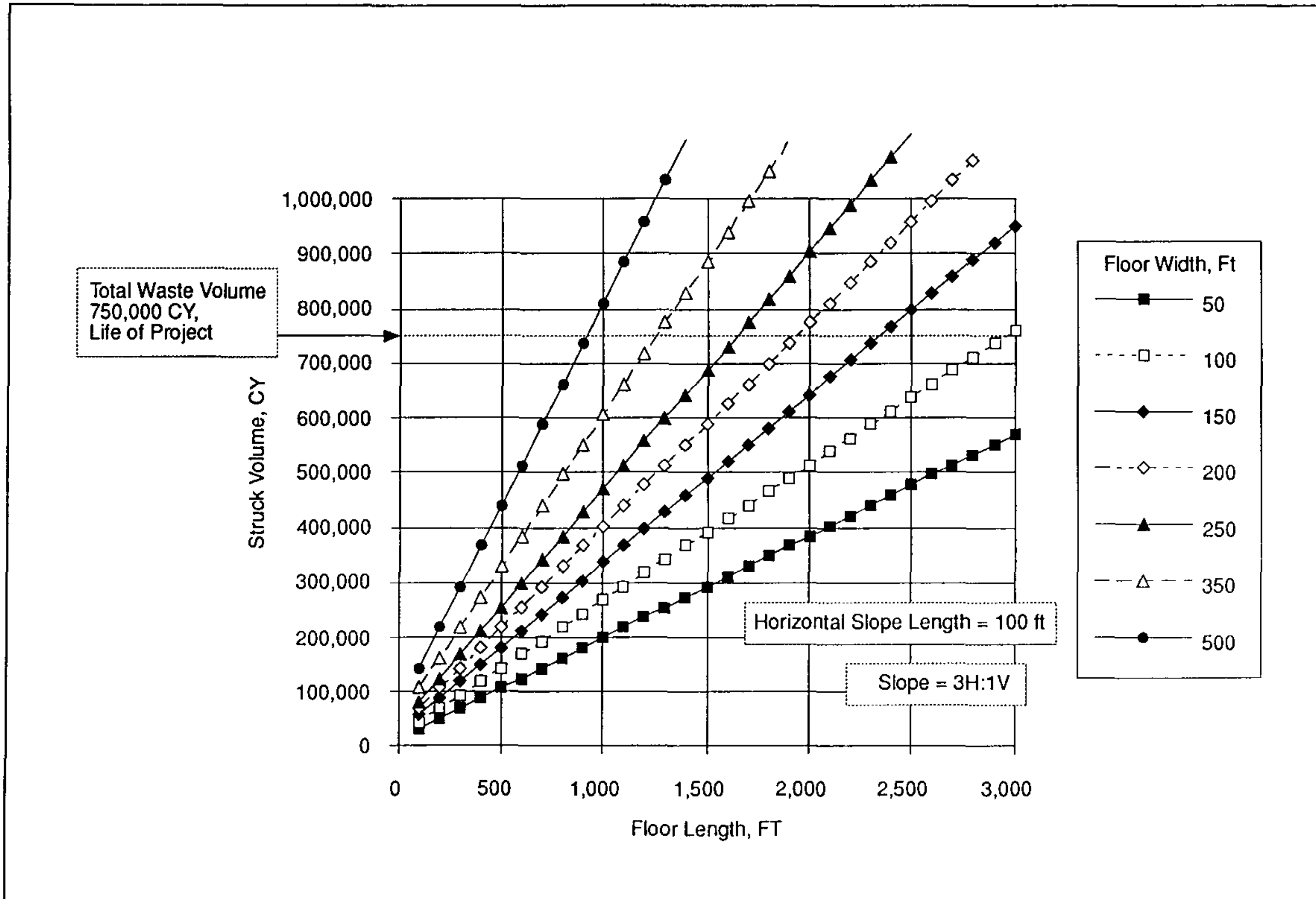


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Figure 3-1. Landfill Airspace as a Function of Length and Width.

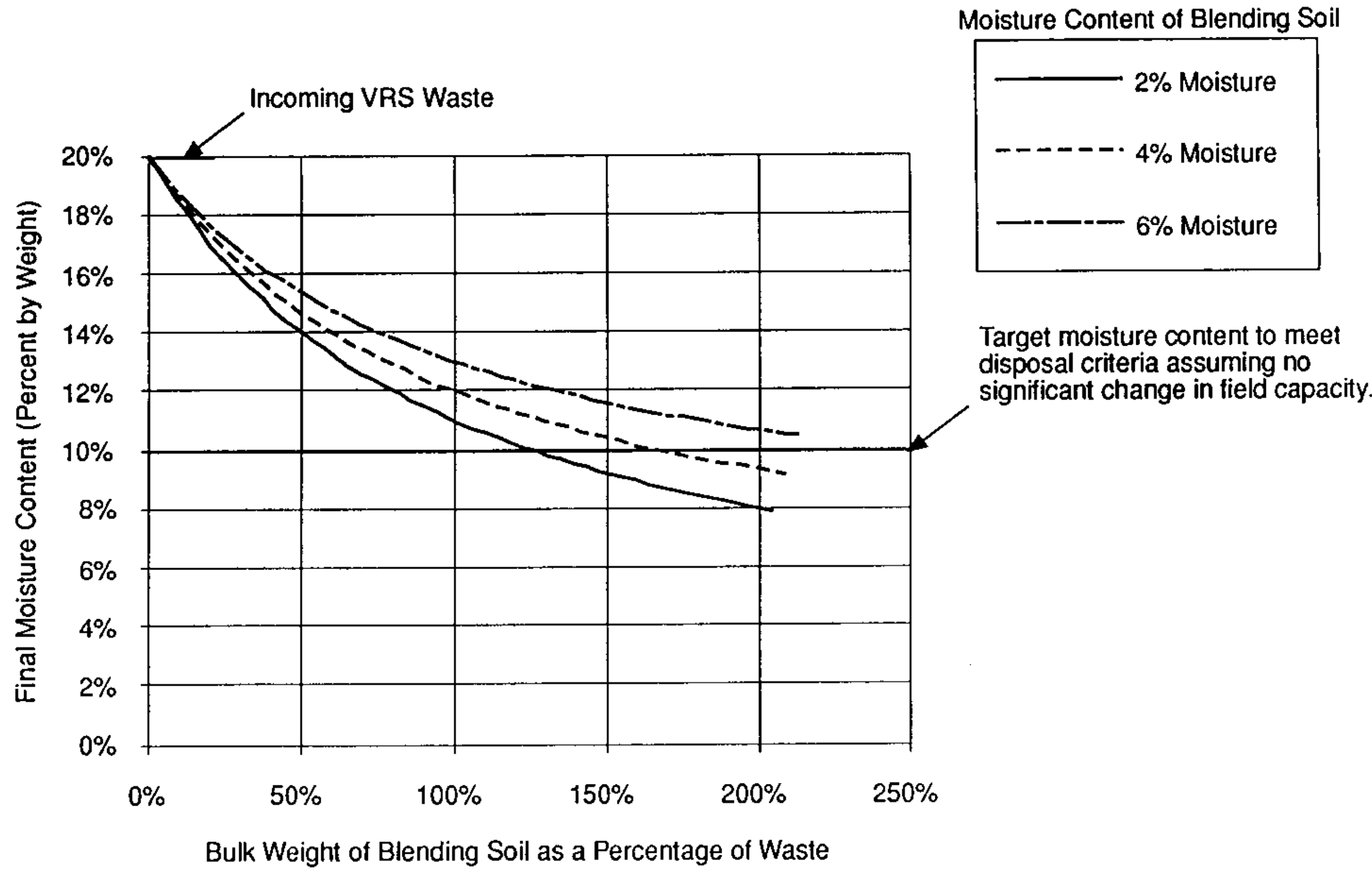

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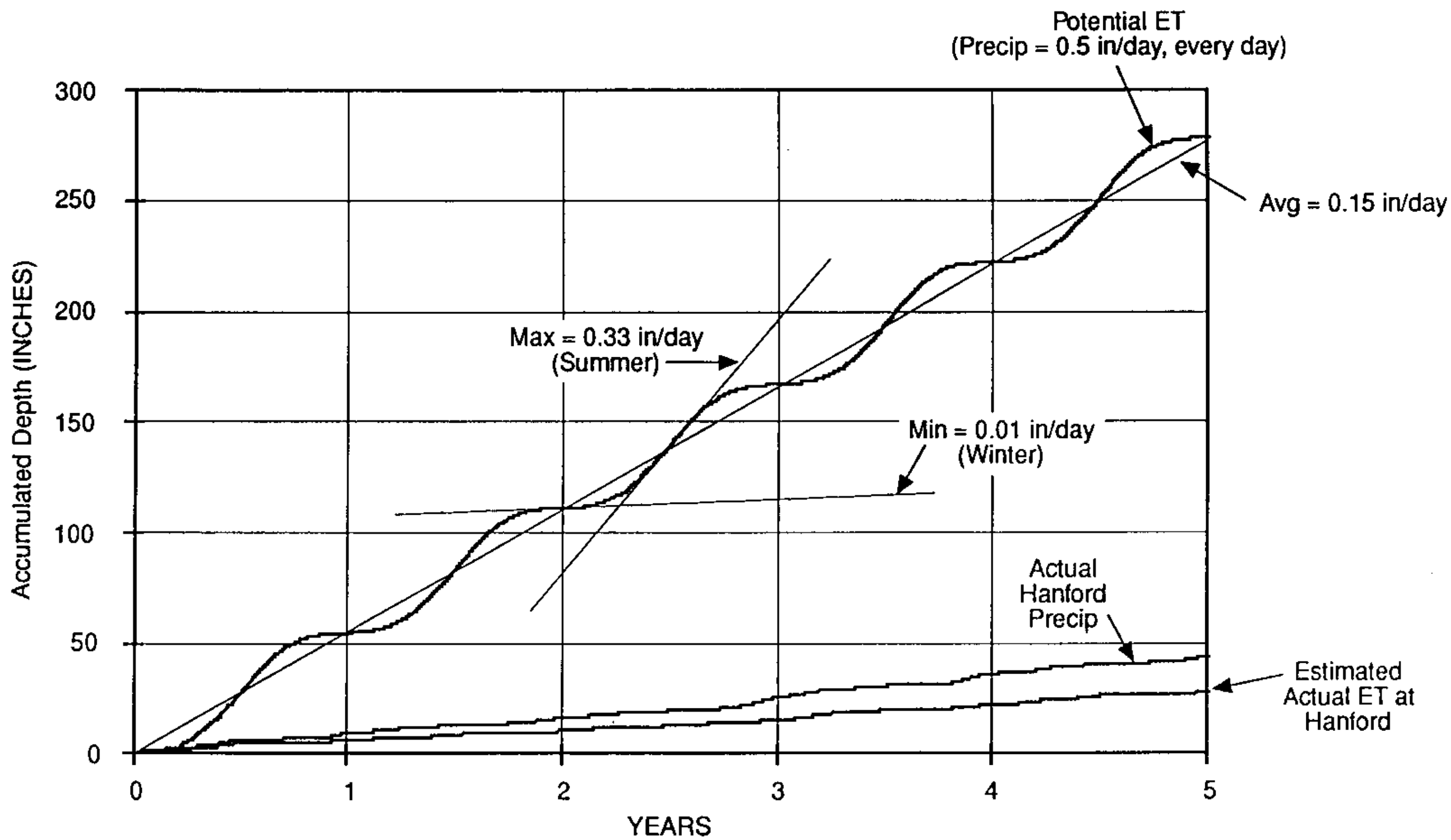
Figure 3-3. Blending Ratios to Meet Moisture Content Criteria.



- Values based on HELP model results
- Maximum potential evapotranspiration (ET) estimated by providing 0.5 inch of precipitation every day

923 A017/41180/7-23-93

Figure 3-4. Variation in Daily Potential Evapotranspiration from Bare Soil at Hanford.

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APPENDIX A
COST ESTIMATES

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A1 LINER SYSTEM

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Golder Associates	SUBJECT Liner System Cost		
	Job No. 923-A017	Made by JCF	Date 6/15/93
	Ref.	Checked	Sheet 1 of 10
		Reviewed [signature]	

ITEM: PREPARE ADMIX — 1

ASSUME: COST TO PREPARE ADMIX FOR NONDRAGOFF IN 1990
8% inflation/year

1990 COST = \$16/CY

1993 COST = $\$16/\text{CY} \cdot (1+.08)^3 = \$20.16/\text{CY}$ ✓

$\text{COST/SF} = \frac{\$20.16}{\text{CY}} \cdot \frac{\text{CY}}{27\text{ft}^3} \cdot \frac{3\text{ft}^3}{1\text{ft}^2} = \$2.24/\text{SF}$ ✓ ←

ITEM: PLACE SECONDARY ADMIX — 1

ASSUME: 1990 COST TO PLACE ADMIX FOR NONDRAGOFF
8% inflation/yr

1990 COST = \$5/CY

1993 COST = $\frac{\$5}{\text{CY}} \cdot (1+0.08)^3 = \frac{\$6.30}{\text{CY}}$ ✓

$\frac{\text{COST}}{\text{SF}} = \frac{\$6.30}{\text{CY}} \cdot \frac{\text{CY}}{27\text{ft}^3} \cdot \frac{3\text{ft}^3}{1\text{ft}^2} = \frac{\$0.70}{\text{SF}}$ ✓ ←

ITEM: SECONDARY ADMIX TRIMMING — 1

ASSUME: 1990 COST TO TRIM ADMIX FOR NONDRAGOFF
8% inflation/yr

1990 COST = \$0.50/SF ✓

1993 COST = $\frac{\$0.50}{\text{SF}} (1+0.08)^3 = \$0.63/\text{SF}$ ←

Golder Associates	SUBJECT LINER SYSTEM COST		
	Job No. 923-A017 Ref.	Made by JPP Checked Reviewed	Date 4/14/93 Sheet 2 of 10

ITEM = SECONDARY 60 MIL TEXTURED HDPE GEOMEMBRANE - 2

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS

COST = $\$0.53/SF$ (see attached telecon)

ITEM = SECONDARY GEOTEXTILE CUSHION BENEATH SECONDARY GRAVEL - 3

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS

COST : $\$0.34/SF$ (see attached telecon)

ITEM: SECONDARY GRAVEL - 4

ASSUME: COST INCLUDES MATERIALS, PLACEMENT AND GRADING
1990 COST FOR SECONDARY GRAVEL FROM NONDRAGOFF
8% inflation/yr

1990 COST = $20/CY

$$1993 \text{ COST} = \frac{\$20}{CY}(1+0.08)^3 = \frac{\$25.19}{CY} \cdot \frac{CY}{27ft^3} \cdot \frac{1ft^3}{1ft^2} = \frac{\$0.93}{SF}$$

ITEM = SECONDARY GEOTEXTILE CUSHION ON TOP OF SECONDARY GRAVEL - 5

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS

COST : $\$0.34/SF$ (see attached telecon)

ITEM: PRIMARY 60 MIL TEXTURED HDPE GEOMEMBRANE - 6

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS

COST : $0.53/SF

Golder Associates	SUBJECT LINER SYSTEM COST		
	Job No. 923-A017	Made by JPP	Date 6/16/93
	Ref.	Checked	Sheet 3 of 10
		Reviewed [signature]	

ITEM: PRIMARY GEOTEXTILE CUSHION BENEATH PRIMARY GRAVEL - 7

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS.

COST: $\$ \frac{0.34}{SF}$ (see attached telecon)

ITEM: PRIMARY DRAINAGE GRAVEL - 8

ASSUME: COST INCLUDES MATERIAL, PLACEMENT AND GRADING
1990 COST FOR PRIMARY GRAVEL FROM NONDRAGOFF
8% inflation/yr

COST: 1990 COST = $20/cy

$$1993 \quad COST = \$\frac{20}{CY}(1+0.08)^3 = \$\frac{25.19}{CY} \cdot \frac{CY}{27ft^3} \cdot \frac{1ft^3}{1ft^2} = \$\frac{0.93}{SF}$$ ✓

ITEM: PRIMARY GEOTEXTILE CUSHION BENEATH PRIMARY GRAVEL - 9

ASSUME: COST INCLUDES MATERIAL AND INSTALLATION, LEVEL D PROTECTION FOR WORKERS

COST: $\$ \frac{0.34}{SF}$ (see attached telecon)

ITEM: OPERATIONS LAYER - 10

ASSUME: COST INCLUDES MATERIAL, PLACEMENT AND GRADING
1990 COST FOR OPERATIONS LAYER FROM NONDRAGOFF
8% inflation/yr

COST: 1990 COST = $2.50/CY

$$1993 \quad COST = \$\frac{2.50}{CY} \cdot \frac{CY}{27ft^3} \cdot \frac{3ft^3}{ft^2} = \$\frac{0.28}{SF}$$

Golder Associates

SUBJECT LINER SYSTEM COST		
Job No. 923-A017	Made by JPP	Date 6/16/93
Ref.	Checked	Sheet 4 of 10
	Reviewed [signature]	

COST SUMMARY

ITEM	COST/SF
PREPARE ADMIX	\$2.24 ✓
PLACE SECONDARY ADMIX	\$0.70 ✓
SECONDARY ADMIX TRIMMING	\$0.63 ✓
SECONDARY HDPE LINER	\$0.53 ✓
SECONDARY GEOTEXTILE (BOTTOM)	\$0.34 ✓
SECONDARY GRAVEL	\$0.93 ✓
SECONDARY GEOTEXTILE (TOP)	\$0.34 ✓
PRIMARY HDPE LINER	\$0.53 ✓
PRIMARY GEOTEXTILE (BOTTOM)	\$0.34 ✓
PRIMARY GRAVEL	\$0.93 ✓
PRIMARY GEOTEXTILE (TOP)	\$0.34 ✓
OPERATIONS LAYER	\$0.28 ✓

$\Sigma =$ \$8.13/SF ✓

SAY \$8.50/SF

PROJECT COST ESTIMATE
NON DRAG-OFF RWM DISPOSAL FACILITY

DESCRIPTION	Qty. Page	QUANTITY	UNIT COST	Unit Cost Ref. Page	TOTAL DOLLARS	SUBTOTALS	
SITE WORK							
MOB-DEMOB		1.0	$30,000.00	1	$30,000		
CLEAR AND GRUB (acres)	1	12.9	$1,100.00	2	$14,190		
EXCAVATION							
landfill							
cut (yd3)	2	81,269.0	$1.50	3	$121,904		
fill (yd3)	2	93.0	$2.50	4	$233		
Staging Area fill (yd3)	2	3,565.0	$2.50	4	$8,913		
trimming (ft2)	11	155,407.0	$0.30	5	$46,622		
sump							
cut(yd3)	3	83.0	$3.00	6	$249		
tank area							
fill (yd3)	6	260.0	$2.50	4	$650		
perimeter road (yd3)							
cut (yd3)	4	217.0	$1.50	3	$326		
fill (yd3)	4	1,701.0	$2.50	4	$4,253		
anchor trench (yd3)							
cut (yd3)	5	1,730.0	$2.00	3	$3,460	Subtotal	$230,798
SOIL LINER CONSTRUCTION							
PREPARE ADMIX (yd3)	10	18,000.0	$16.00	8	$288,000		
SECONDARY CLAY (yd3)	10	14,624.0	$5.00	9	$73,120		
Trimming clay (ft2)	11	155,407.0	$0.50	5	$77,704		
SECONDARY GRAVEL (yd3)	15	1,053.0	$20.00	12	$21,060		
SECONDARY SUMP GRAVEL (yd3)	13	44.0	$20.00	12	$880		
PRIMARY GRAVEL (yd3)	15	1,134.0	$20.00	12	$22,680		
PRIMARY SUMP GRAVEL (yd3)	14	66.0	$20.00	12	$1,320		
OPERATIONS LAYER (yd3)	23	6,341.0	$2.50	4	$15,853	Subtotal	$500,616

PROJECT COST ESTIMATE

NON DRAG-OFF RWM DISPOSAL FACILITY

DESCRIPTION	Qty. Page	QUANTITY	UNIT COST	Unit Cost Ref. Page	TOTAL DOLLARS	SUBTOTALS	
GEOSYNTHETIC LINER							
SECONDARY HDPE							
slope (ft2)	11	129,612.0	$0.60	11	$77,767		
floor (ft2)	11	24,346.0	$0.50	11	$12,173		
SECONDARY DRAIN-SLOPES (ft2)	11	129,612.0	$0.66	11	$85,544		
SECONDARY DRAIN-FLOOR							
geotextile (ft2)	11	24,346.0	$0.25	10	$6,086		
geonet (ft2)	11	24,346.0	$0.28	10	$6,817		
PRIMARY HDPE							
slope (ft2)	12	126,916.0	$0.60	11	$76,150		
floor (ft2)	12	27,853.0	$0.50	11	$13,927		
PRIMARY DRAIN-SLOPES (ft2)	12	126,916.0	$0.66	11	$83,105		
PRIMARY DRAIN-FLOOR							
geotextile (ft2)	12	27,853.0	$0.11	10	$3,064		
geotextile (ft2)	12	55,700.0	$0.25	10	$13,925		
geonet (ft2)	12	27,853.0	$0.28	10	$7,799		
HDPE FLATSTOCK (FT2)	D	16.0	$30.00		$480		
HDPE, TRUCK STAGING AREA (ft2)	7	9,716.0	$0.80	11	$7,773	Subtotal	$394,006
MISC. EARTHWORKS							
ROADBASE, ENTRANCE (yd3)	17	65.0	$20.00	12	$1,300		
V DITCH CONSTRUCTION (yd3)	16	842.0	$1.50		$1,263		
ROADBASE, PERIMETER ROAD (yd3)	17	928.0	$20.00	12	$18,560		
ROADBASE, 8% RAMP (yd3)	17	132.0	$20.00	12	$2,640		
STAGING AREA GRAVEL (yd3)	7	432.0	$20.00	12	$8,640		
STAGING AREA PAVEMENT (yd2)	7	1,080.0	$11.80	M	$12,744		
ANCHOR TRENCH BACKFILL (yd3)	5	1,730.0	$3.50	4	$6,055	Subtotal	$51,202

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PROJECT COST ESTIMATE
NON DRAG-OFF RWM DISPOSAL FACILITY

DESCRIPTION	Qty. Page	QUANTITY	UNIT COST	Unit Cost Ref. Page	TOTAL DOLLARS	SUBTOTALS	
LEACHATE COLLECTION SYSTEM							
SECONDARY 8" HDPE SLOPE RISER (ft)	18	104.5	$12.00	27	$1,254		
SECONDARY 1" PVC SENSOR PIPE (ft)	18	209.0	$5.00	27	$1,045		
SECONDARY 2" HDPE SENSOR PIPE (ft)	18	209.0	$8.00	27	$1,672		
SECONDARY 1.5" HDPE PUMP PIPE (ft)	21	121.0	$8.00	27	$968		
PRIMARY 8" HDPE SLOPE RISER (ft)	18	105.5	$12.00	27	$1,266		
PRIMARY 1" PVC SENSOR PIPE (ft)	18	211.0	$5.00	27	$1,055		
PRIMARY 2" HDPE SENSOR PIPE (ft)	18	211.0	$8.00	27	$1,688		
PRIMARY 1.5" HDPE PUMP PIPE (ft)	21	234.0	$8.00	27	$1,872		
PRIMARY 3" HDPE PUMP PIPE (ft)	21	176.0	$10.00	27	$1,760		
TURBINE METER	21	1.0	$2,140.00	18	$2,140		
CHECK VALVES (1.5 inch)	21	2.0	$100.00	EST	$200	W51,52	
CHECK VALVES (3 inch)	26	1.0	$100.00	EST	$100	W53	
SOLENOID DRAIN DOWN VALVE	26	1.0	$100.00	EST	$100	W54	
PRIMARY VERTICAL STAINLESS							
STEEL 4" PUMP PIPE (ft)	24	26.0	$67.00	22	$1,742		
STAINLESS STEEL 90 DEG ELBOWS	24	6.0	$100.00	22	$600		
PIPE SUPPORT	24	LS	$600.00	EST	$600		
RISER CREST PAD CONCRETE	19	4.1	$500.00	M	$2,050		
VERTICAL RISER BASE	D	1.0	$500.00	M	$500		
VERTICAL RISER SECTION	D	12.0	$120.00	M	$1,440		
30 IN HDPE PIPE (ft)	D	6.0	$100.00		$600		
4 IN HDPE PERFORATED PIPE (ft)	20	1,325.0	$11.00	M	$14,575		
SECONDARY SLOPE RISER PUMP	26	1.0	$1,500.00		$1,500	W5P2	
PRIMARY SLOPE RISER PUMP	26	1.0	$1,500.00		$1,500	W5P1	
PRIMARY VERTICAL RISER PUMP	D	1.0	$9,000.00	21	$9,000	W5P3	
STORAGE TANK TRANSFER PUMP	D	1.0	$2,800.00	20	$2,800	W5P4	
PRIMARY RISER SENSORS	26	1.0	$1,500.00		$1,500		
SECONDARY RISER SENSORS	26	1.0	$1,500.00		$1,500		
STAINLESS STEEL 2" SUCTION PIPE	D	10.0	$25.00	22	$250		
VACUUM RELEASE VALVE	D	3.0	$100.00	EST	$300	58,W59,W60	
TRANSFER PUMP ISOLATION VALVE	D	1.0	$100.00	EST	$100	W57	
STAINLESS STEEL CABLE,	D	LS	$400.00	23	$400		
STORAGE TANK	D	1.0	$20,000.00	18	$20,000		
STORAGE TANK CONCRETE (yd3)	19	20.0	$500.00	M	$10,000		
FLOAT SWITCHES	26	2.0	$175.00	EST	$350		
CONCRETE COATING (ft2)	25	1,387.0	$4.00	M	$5,548	Subtotal	$91,975

PROJECT COST ESTIMATE
NON DRAG-OFF RWM DISPOSAL FACILITY

DESCRIPTION		Qty. Page	QUANTITY	UNIT COST	Unit Cost Ref. Page	TOTAL DOLLARS	SUBTOTALS	
CONTROL PANEL AND BUILDING								
	CONTROL PANEL	D	1.0	$3,000.00	EST	$3,000		
	CONTROL BUILDING	D	1.0	$3,500.00	EST	$3,500	Subtotal	$6,500
ELECTRICAL SERVICE AND LIGHTING		D	1.0	$26,000.00	S	$26,000	Subtotal	$26,000
					Subtotal	$1,301,096		$1,301,096
					Total	1,301,096		1,301,096

EST – GAI Estimate
M – Estimate based on Means Site Work Cost Data – 1989
S – Estimated by Sparling & Associates, Inc.
D – Quantity indicated on Drawings

723-22-3

8/10

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

FILE: 3.2.1

DATE: 6/14/93
PAGE 1 OF 1

PROJECT CONTACT REPORT

U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Geosynthetic Costs

Discussion:

Costs do not include sales tax and waste

Assume quantity of 200,000 ft²

Trevira 1125 - \$0.08/sf (materials) + \$0.15/sf (install) = \$0.23/sf

Trevira 1155 - \$0.19/sf (materials) + \$0.15/sf (install) = \$0.34/sf

60 mil textured HDPE (both sides) = \$0.25/sf + \$0.28/sf = \$0.53/sf

PN-3000 = \$0.18/sf + \$0.15/sf = \$0.33/sf

Geocomposite (PN3000 + 1125 on both sides) = \$0.30/sf + \$0.15/sf = \$0.45/sf

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSDF DESIGN STUDIES/WA	Organization's Name: National Seal Co.
Employee's Name: John Pellicer	Address:
Employee's Company: Golder Assoc.	Phone No.: (714) 753-9200
Date: 6/14/93 Time:	Person's Name: Wayne Johanson

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

DISTRIBUTION:

☐ JMM
☒ File

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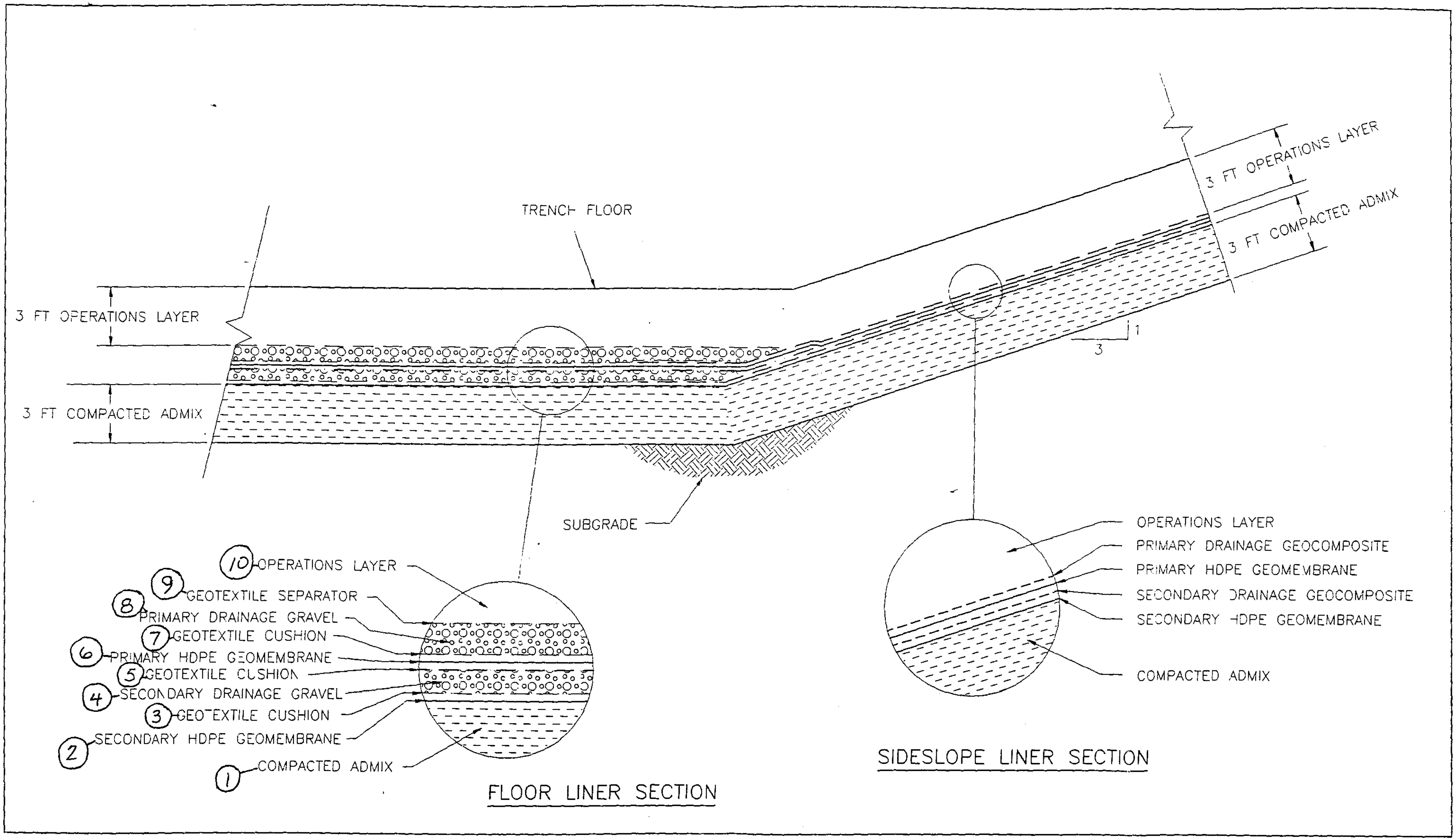

923-A017 42582

Figure 1-2. Liner System Section

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A2 EXPANSION OF EXISTING TREATMENT FACILITIES

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Golder Associates	SUBJECT Expansion of Existing Treatment Facility		
	Job No. 923-A017	Made by JPP	Date 6/15/93
	Ref.	Checked	Sheet 1 of 7
		Reviewed MBrown	

ITEM: INITIAL CAPITAL [illegible] EXPANDING EXISTING TREATMENT FACILITY

ASSUMPTIONS:
- 150 ft x 150 ft Building for drum processing
- drum processing rate 2.5 drums/minute
- 13 process lines to stabilize drums
- Process lines would have conveyor systems which would add absorbent and mix drum
- 4 forklifts to load drums on conveyor systems
- 4 forklifts to unload conveyor systems
- 4 flatbeds trucks to haul drums from treatment facility to landfill
- 4 forklifts to unload drums [illegible] trucks
- Landfill compactor will spread drum [illegible] drums

- Building cost, assume $75/sq ft to build

Cost = ($75/ft²)(150 ft)² = $1,687,500 = $1.7 million

Assume $ 2 million for process line

TOTAL BUILDING COST + EQUIPMENT = $3.7 million

Equipment Cost = (8 forklifts)($40,000/each) = $160,000 (telecon)

(4 flatbeds)($100,000/each) = $400,000 ([illegible])

(4 forklifts)($80,000/each) = $320,000 (telecon)

816 Landfill Compactor = $200,000 (telecon)

Total Equipment Cost For Transportation = $1,080,000

Total Equipment + Building Cost = $4,780,000 ~ $5,000,000

Golder Associates

SUBJECT Expansion of Existing Treatment Facility		
Job No. 923-A017	Made by JPP	Date 1/5/93
Ref.	Checked	Sheet 2 of 7
	Reviewed [illegible]	

ITEM ANNUAL OPERATING COST

- Equipment OWNER + OPERATING COST $\frac{\$10}{HR}$ (assume)

$$(17_{pieces})\left(\frac{3\,hr}{shift}\right)\left(\frac{\$10}{HR}\right)\left(\frac{390\,shift}{yr}\right) = \$\,530{,}400/yr$$
$$\sim \$\,550{,}000/yr$$

- OPERATOR COST

Process Line $\left(\frac{4\,persons}{line}\right)(15\,lines)\left(\frac{\$20}{HR}\right)\left(\frac{3\,hr}{shift}\right)\left(\frac{390\,shift}{yr}\right) = \$3{,}744{,}000/yr$

Equipment Operators $(17_{operators})\left(\frac{\$20}{HR}\right)\left(\frac{3\,hr}{shift}\right)\left(\frac{390\,shift}{yr}\right) = \$1{,}060{,}800/yr$

EQUIPMENT OPERATION TOTAL = \$4,855,000/yr

- ABSORBENT COST

$\frac{75{,}000\,cy}{yr} \cdot \frac{27\,ft^3}{CY} \cdot \frac{70\,lb}{ft^3} \cdot \frac{0.2\,lb\,H_2O}{1\,lb\,waste} \cdot \frac{1\,lb\,absorb}{2\,lb\,H_2O} \cdot \frac{\$0.25\ \text{for}}{1\,lb\,absorb} = \$\,3{,}543{,}000/yr$

- DRUM COST

$\frac{\$20\ \text{telecon}}{bbl} \cdot \frac{75{,}000\,cy}{yr} \cdot 1.1\,bulking \cdot \frac{27\,ft^3}{cy} \cdot \frac{7.48\,gal}{ft^3} \cdot \frac{bbl}{55\,gal} = \$6{,}058{,}800/yr$

TOTAL ANNUAL OPERATING COST = \$ 15,007,400/yr

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PROJECT CONTACT REPORT

DATE: 6/15/93
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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Equipment Costs

Discussion:

D-5 Dozer - $140,000

816 Landfill Compactor - $200,000

966 Front End Loader - $220,000

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSOF DESIGN STUDIES/WA	Organization's Name: N.C. Machinery Co.
Employee's Name: John Pellicer	Address: Tukwila, WA
Employee's Company: Golder Assoc.	Phone No.: (206) 251-5800
Date: 6/15/93 Time: 8:00 Am	Person's Name: John Kurtz

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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PROJECT CONTACT REPORT

DATE: 6/15/93
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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: OWNER + OPERATING COSTS

Discussion:

OWNERSHIP + OPERATING COSTS FOR

850 DOZER ~ D6 : Operation = $35/hr + Ownership $20/hr = $55/hr

825 Compactor ~ 816 Compactor = $30/hr Operations + $25/hr Ownership = $55/hr

966 Loader ~ $20/hr Operation + $30/hr Ownership = $50/hr

JMM PARTY	OTHER PARTY
Project Name: JMM/COE/ERSDF DESIGN STUDIES/CWT	Organization's Name: Wilder Construction
Employee's Name: John Pellicer	Address: Spokane
Employee's Company: Golder Assoc.	Phone No.: (509) 838-6414
Date: 6/15/93 Time:	Person's Name: Mike Kangas

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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PROJECT CONTACT REPORT

DATE: 6/15/93
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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Forklift Costs

Discussion:

Minimum Lifting Capacity = 10,000 lbs

$80,000 for forklift that can operate on rough terrain in Landfill

$40,000 for forklift that works on concrete slab.

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/GOLDER DESIGN STUDIES/CWA	Organization's Name: Clarklift
Employee's Name: John Pellicer	Address:
Employee's Company: Golder Assoc.	Phone No.: (206) 762-7440
Date: 6/15/93 Time:	Person's Name:

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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923-A017 017

UPRIGHT
INCORPORATED

10665 Kahlmeyer Drive, St. Louis, MO 63132
(314) 426-3336 (800) 248-7007
Fax: (314) 426-0145

FAX FAX FAX

DATE: 6-11-93 # OF PAGES: 11 (including cover)

TO: NAME/COMPANY: Randy Narbug / Golder Assoc.

FAX NO. (206) 882-5498

MESSAGE: Per our telephone discussion. Any questions, please call us.

Thank you.

Joe Lebryk (Joe LEBRYK)
UPRIGHT, Inc.

Absorbent Products

810$/2000 lb ⇒ ~ 50¢/lb.

will absorb twice it's own weight —

bulking unknown

25¢/lb of water absorbed.

total/year = 454000 ft³/year =

75000 CY/year ⇒

= ½ absorbed

14 164 800

3 500 000

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC. FILE: 3.2.1

PROJECT CONTACT REPORT

DATE: 6/15/93
PAGE 1 OF 1

U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Drum Cost

Discussion:

Reconditioned, 17H, w/ removable lid, best price would be $20/barrel for 55gal steel.

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSDF DESIGN STUDIES/WA	Organization's Name: Northwest Cooperage Co. Inc.
Employee's Name: John Pellicer	Address:
Employee's Company: Golder Assoc.	Phone No.: (206) 763-2345
Date: 6/15/93 Time: 12:20 pm	Person's Name: Coleen

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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A3 CHEMICAL ADDITIVES

CEMENT
LIME
ABSORBENTS

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Golder Associates	SUBJECT Cost Estimate For Chemical Additive Treatment		
	Job No. 923-A017	Made by JPP	Date 6/15/93
	Ref.	Checked	Sheet 1 of 7
		Reviewed [illegible signature]	

ITEM: Initial Capital Outlay for Equipment

Assume: - waste end dumped in landfill @ no cost
- Landfill compactor to spread and compact waste
- Dozer to spread waste and pull tilling equipment
- Tilling equipment to mix waste and chemical additive + aeration [illegible]
- Spreading equipment to apply chemical [illegible]
- Loader to load chemical additive to spreader

Construction Equipment Costs: 816 Landfill Compactor : $ 200,000 (telecon)
D5 Dozer : $ 140,000 (telecon)
966 Loader : $ [illegible],000 (telecon)
Spreader : $ [illegible],000 ([illegible])
Tilling Equipment : $ [illegible],000 ([illegible])
Σ = $ 620,000

ITEM: ANNUAL OPERATING COST (CEMENT)

- OPERATING + OWNERSHIP COST = $ 55/HR (telecon)

$$(3\ \text{pieces})\left(\frac{\$55}{HR}\right)\left(\frac{8\ Hr}{shift}\right)\left(\frac{390\ shift}{yr}\right) = \$514{,}800/yr$$

- OPERATOR COST = $ 20/HR ([illegible])

(3 operators) ($\frac{\$20}{HR}$) ($\frac{8\ Hr}{shift}$) ($\frac{[illegible]\ shift}{yr}$) [illegible] $ [illegible]/yr

- Cost of Cement = $ 7[illegible]/ton (telecon)

Apply @ 10% of waste weight

$\frac{75,000\ cy}{yr}$ · $\frac{27\ ft^3}{cy}$ · $\frac{[illegible]}{ft^3}$ · (0.10) [illegible] = $ [illegible]/yr

TOTAL ANNUAL [illegible] = $ [illegible] + [illegible] + [illegible] [illegible] ≈ $ [illegible]

Golder Associates	SUBJECT [illegible]		
	Job No. [illegible] Ref.	Made by [illegible] Checked Reviewed [illegible]	Date [illegible] Sheet 2 of 7

ITEM: ANNUAL OPERATING COST (ABSORBENT)

- OPERATING + OWNERSHIP COST $514,800 (see pg. 1)
- OPERATOR COST - $187,200/yr (see pg. 1)
- COST OF ABSORBENT : $0.25/lb OF WATER ABSORBED

$$\left(\frac{75{,}000\,CY}{yr}\right)\left(\frac{27\,ft^3}{CY}\right)\left(\frac{70\,lb}{ft^3}\right)\left(\frac{0.2\,lb\,H_2O}{1\,lb\,wash}\right)\left(\frac{1\,lb\,absorbent}{2\,lb\,H_2O}\right)\left(\frac{\$0.25}{1\,lb\,absorb}\right) - \$3{,}543{,}750$$

TOTAL ANNUAL OPERATING COST : $514,800
$187,200
$3,543,000

$4,245,000 ~ $4,300,000/yr

ITEM: ANNUAL OPERATING COST (LIME)

- OPERATING + OWNERSHIP COST : $514,800 (see pg. 1)
- OPERATOR COST : $187,200/yr (see pg. 1)
- Cost of lime = $150/ton added @ 4% by weight (telecon)

$$\frac{75{,}000\,cy}{yr} \cdot \frac{27\,ft^3}{cy} \cdot \frac{70\,lb}{ft^3} \cdot (0.04)\frac{ton}{2000\,lb} \cdot \frac{\$156}{ton} = \$442{,}260/yr$$

TOTAL ANNUAL OPERATING COST = $514,800 + 187,200 + 442,260 = $1,144,260/yr
~ $1,150,000/yr

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PROJECT CONTACT REPORT

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Cement Cost

Discussion:

Quantity ~ 7000 ton/yr

Cost ~ $78/ton delivered to site

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSDF DESIGN STUDIES/WA	Organization's Name: ASH GROVE
Employee's Name: John Pellicer	Address: SPOKANE
Employee's Company: Golder Assoc	Phone No.: (509) 536-6300
Date: 6/15/93 Time:	Person's Name: Ken Burnside

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Lime Costs

Discussion:

Quantity ~ 4000 ton/yr

Hydrated Lime (powder) = $156/ton

Quicklime (pellets) = $132/ton

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSDF DESIGN STUDIES/WA	Organization's Name: Great Western Chemical
Employee's Name: John Pellicer	Address:
Employee's Company: Golder Assoc.	Phone No.: (509) 545-4296
Date: 6/15/93 Time:	Person's Name:

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Equipment Costs

Discussion:

D-5 Dozer - $140,000

816 Landfill Compactor - $200,000

966 Front End Loader - $220,000

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSOF DESIGN STUDIES/WA	Organization's Name: N.C. Machinery Co.
Employee's Name: John Pellicer	Address: Tukwila, WA
Employee's Company: Golder Assoc.	Phone No.: (206) 251-5800
Date: 6/15/93 Time: 8:00 Am	Person's Name: John Kurtz

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: OWNER + OPERATING COSTS

Discussion:

OWNERSHIP + OPERATING COSTS FOR

850 DOZER ~ D6 : Operation = $35/hr + Ownership $20/hr = $55/hr

825 Compactor ~ 816 Compactor = $30/hr Operations + $25/hr Ownership : $55/hr

966 Loader ~ $20/hr Operation + $30/hr Ownership = $50/hr

JMM PARTY	OTHER PARTY
Project Name: JMM/COE/EKSPP DESIGN STUDIES/WA	Organization's Name: Wilder Construction
Employee's Name: John Pellicer	Address: Spokane
Employee's Company: Golder Assoc.	Phone No.: (509) 838-6414
Date: 6/15/93 Time:	Person's Name: Mike Kangas

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Absorbent Cost

Discussion:

\$810/2000lb ~ \$0.50/lb

Material absorbs twice its own weight, ∴ \$0.25/lb of water absorbed

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSDF DESIGN STUDIES/WA	Organization's Name: Upright Incorporated
Employee's Name: MIKE BROWN	Address: 10665 Kahlmeyer Drive, St. Louis, MO
Employee's Company: Golder Assoc	Phone No.: (314) 426-3336
Date: 6/11/93 Time:	Person's Name: Joe Lebryk

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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A4 BLENDING WITH ERSDF WASTE

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ITEM: Initial Capital Outlay for Equipment

Assumptions:
- VRS waste end dumped @ no cost in Landfill
- EKSDF waste end dumped @ no cost in landfill
- 1.5 parts EKSDF Waste to 1 part VRS waste
- Landfill compactor to spread + compact waste
- Tilling Equipment to mix the waste

Equipment Cost: 816 Compactor : $200,000 (telecon)
[illegible]
[illegible]

Σ COST = $350,000

ITEM: ANNUAL OPERATING COST

- OPERATING + OWNER COST $55/HR (telecon)

$$(2\text{ pieces})\left(\frac{\$55}{HR}\right)\left(\frac{8\ HR}{shift}\right)\left(\frac{390\ shift}{yr}\right) = \frac{\$343,200}{yr}$$

- OPERATOR COST = $\frac{\$20}{HR}$ (assumed)

$$(2\text{ operators})\left(\frac{\$20}{HR}\right)\left(\frac{8\ HR}{shift}\right)\left(\frac{390\ shift}{yr}\right) = \$124,800/yr$$

Σ ANNUAL COST = $468,000/yr ~ $500,000/yr

123-1101 +

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PROJECT CONTACT REPORT

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Equipment Costs

Discussion:

D-5 Dozer - $140,000

816 Landfill Compactor - $200,000

966 Front End Loader - $220,000

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSOF DESIGN STUDIES/WA	Organization's Name: N.C. Machinery Co.
Employee's Name: John Pellicer	Address: Tukwila, WA
Employee's Company: Golder Assoc.	Phone No.: (206) 251-5800
Date: 6/15/93 Time: 8:00 Am	Person's Name: John Kurtz

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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PROJECT CONTACT REPORT

DATE: 6/15/93
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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: OWNER + OPERATING COSTS

Discussion:

OWNERSHIP + OPERATING COSTS FOR

850 DOZER ~ D6 : Operation = $35/hr + Ownership $20/hr = $55/hr

825 Compactor ~ 816 Compactor = $30/hr Operations + $25/hr Ownership = $55/hr

966 Loader ~ $20/hr Operation + $30/hr Ownership = $50/hr

JMM PARTY	OTHER PARTY
Project Name: JMM/COE/ERSDF DESIGN STUDIES/CWA	Organization's Name: Wilder Construction
Employee's Name: John Pellicer	Address: Spokane
Employee's Company: Golder Assoc.	Phone No.: (509) 838-6414
Date: 6/15/93 Time:	Person's Name: Mike Kangas

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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A5 BLENDING WITH ON-SITE SOILS

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Golder Associates	SUBJECT Cost Estimate for Blending w/ on-site soil		
	Job No. 923-A017	Made by JPR	Date 5/16/93
	Ref.	Checked	Sheet 1 of 3
		Reviewed [signature]	

ITEM: Initial Capital outlay for equipment

Assume: - VRS waste is end dumped in landfill @ no cost
- MIXING SOIL CONSISTS OF EXCAVATION SOIL STOCKPILED NEXT THE EXCAVATION
- ~ 1.5 parts blending soil to 1 part VRS waste
- Landfill compactor to spread and compact waste
- Dozer to spread waste & mix soil
- 2 scrapers to haul blending soil

Construction Equipment Cost:

816 landfill Compactor	\$200,000	(telecon)
D5 Dozer	\$150,000	(telecon)
Tilling Equipment	\$50,000	(assume)
615 Scraper	\$250,000	(assume)
615 Scraper	\$250,000	(assume)

Σ COST = \$850,000

ITEM: ANNUAL OPERATING COST

- OPERATING + OWNERSHIP COST FOR EQUIPMENT EXCEPT SCRAPERS : $\$ \frac{55}{HR}$ (telecon)

- INCREASE OPERATING COST OF SCRAPERS BY \$20/HR FOR DECONNING WHEN HAULING MIXING DIRT INTO LANDFILL : $\$ \frac{75}{HR}$ (assume)

$$(2\text{ pieces})\left(\frac{\$55}{HR}\right)\left(\frac{8\,HR}{shift}\right)\left(\frac{390\text{ shift}}{yr}\right) + (2\text{ pieces})\left(\frac{\$75}{HR}\right)\left(\frac{8\,Hr}{shift}\right)\left(\frac{390\text{ shift}}{yr}\right) = \$811,200/yr$$

- OPERATOR COST = $(4\text{ operators})\left(\frac{\$20}{HR}\right)\left(\frac{8\,hr}{shift}\right)\left(\frac{390\text{ shift}}{yr}\right) = \$249,600/yr$

Σ ANNUAL COST = 811,200 + 249,600 = \$1,060,800/y ~ \$1,100,000/yr

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

FILE: 3.2.1

PROJECT CONTACT REPORT

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Equipment Costs

Discussion:

D-5 Dozer - $140,000

816 Landfill Compactor - $200,000

966 Front End Loader - $220,000

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSOF DESIGN STUDIES/WA	Organization's Name: N.C. Machinery Co.
Employee's Name: John Pellicer	Address: Tukwila, WA
Employee's Company: Golder Assoc.	Phone No.: (206) 251-5800
Date: 6/15/93 Time: 8:00 Am	Person's Name: John Kurtz

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: OWNER + OPERATING COSTS

Discussion:

OWNERSHIP + OPERATING COSTS FOR

850 DOZER ~ D6 : Operation = $35/hr + Ownership $20/hr = $55/hr

825 Compactor ~ 816 Compactor = $30/hr Operations + $25/hr Ownership = $55/hr

966 Loader ~ $20/hr Operation + $30/hr Ownership = $50/hr

JMM PARTY	OTHER PARTY
Project Name: JMM/COE/OSOP DESIGN STUDIES/CWA	Organization's Name: Wilder Construction
Employee's Name: John Pellicer	Address: Spokane
Employee's Company: Golder Assoc.	Phone No.: (509) 838-6414
Date: 6/15/93 Time:	Person's Name: Mike Kangas

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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A6 ENHANCED EVAPORATION

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Golder Associates	SUBJECT Cost Estimate for Evaporation Enhancement		
	Job No. 923-A017	Made by JPP	Date 6/16/93
	Ref.	Checked	Sheet 1 of 3
		Reviewed MJBrown	

ITEM - INITIAL STARTUP COST

ASSUME: - VRS waste is end dumped in landfill @ no cost
- Landfill compactor to spread + compact waste
- Dozer to spread + fill waste for aeration
- Scraper to move stockpile

Construction Equipment Cost: 816 Landfill Compactor : \$200,000 (telecom)
D5 Dozer : \$140,000 (telecom)
631 Scraper : \$ [illegible] ([illegible])
Tilling Equipment : \$ [illegible] ([illegible])

Σ COST = \$600,000

ITEM - ANNUAL OPERATING COST

- OPERATING + OWNER COST = \$55/HR (telecom)

$$(3\ \text{pieces})\left(\frac{\$55}{HR}\right)\left(\frac{8\ Hr}{shift}\right)\left(\frac{390\ shift}{yr}\right) = \$514{,}800/yr$$

- Operator Cost = \$20/HR (assume)

$$(3\ \text{operators})\left(\frac{\$20}{HR}\right)\left(\frac{8\ HR}{shift}\right)\left(\frac{390\ shift}{yr}\right) = \$187{,}200/yr$$

$$\Sigma\ \text{ANNUAL COST} = \$702{,}000/yr \sim \$700{,}000/yr$$

923-A017 2/3

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC. FILE: 3.2.1

PROJECT CONTACT REPORT

DATE: 6/15/93
PAGE 1 OF 1

U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: Equipment Costs

Discussion:

D-5 Dozer - $140,000

816 Landfill Compactor - $200,000

966 Front End Loader - $220,000

JMM PARTY	OTHER PARTY
Project Name: COE/JMM/ERSOF DESIGN STUDIES/WA	Organization's Name: N.C. Machinery Co.
Employee's Name: John Pellicer	Address: Tukwila, WA
Employee's Company: Golder Assoc.	Phone No.: (206) 251-5800
Date: 6/15/93 Time: 8:00 Am	Person's Name: John Kurtz

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

DISTRIBUTION:

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JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

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DATE: 6/15/93
PAGE 1 OF 1

U.S. CORPS OF ENGINEERS
WALLA WALLA DISTRICT

CONTRACT NO. DACW68-92-D-0001
DELIVERY ORDER NO. 17

Subject: OWNER + OPERATING COSTS

Discussion:

OWNERSHIP + OPERATING COSTS FOR

850 DOZER ~ D6 : Operation = \$35/hr + Ownership \$20/hr = \$55/hr

825 Compactor ~ 816 Compactor = \$30/hr Operations + \$25/hr Ownership : \$55/hr

966 Loader ~ \$20/hr Operation + \$30/hr Ownership = \$50/hr

JMM PARTY	OTHER PARTY
Project Name: JMM/COE/ESDP DESIGN STUDIES/WA	Organization's Name: Wilder Construction
Employee's Name: John Pellicer	Address: Spokane
Employee's Company: Golder Assoc.	Phone No.: (509) 838-6414
Date: 6/15/93 Time:	Person's Name: Mike Kangas

CALL PLACED BY: JMM ☒ OTHER PARTY ☐

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A7 MECHANICAL (THERMAL) DEWATERING

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Golder Associates

SUBJECT Mechanical Dewatering Cost Estimate		
Job No. 923-A017	Made by	Date
Ref.	Checked	Sheet 1 of 3
	Reviewed	

Waste handled per shift = $\frac{75{,}000\,cy}{yr} \cdot \frac{yr}{390\ shifts} = \frac{192\,cy}{shift}$

Weight = $\frac{192\,cy}{shift} \cdot \frac{27\,ft^3}{1\,cy} \cdot \frac{70\,lb}{ft^3} = 362{,}880\ \frac{lb}{shift}$ Waste @ 20% moisture

Weight of water/shift = $(.2)(362{,}880\ \frac{lb}{shift}) = 72{,}576\ \frac{lb}{shift}$

Weight of soil/shift = $362{,}880 - 72{,}576 = 290{,}304\ \frac{lb}{shift}$ dry soil

Total Volume of H_2O = $72{,}576\ \frac{lb\ H_2O}{shift} \cdot \frac{ft^3}{62.4\,lb} = 1162\ ft^3 \sim 43\ cy$

Volume of dry soil = $192 - 43 = 149\ cy$

Estimate volume of slurry from soil washing process, assume after settling slurry is 90% liquid, 10% solids.

Volume slurry per shift = $\frac{149\,cy}{.1} = 1490\ \frac{cy}{shift}$ @ 10% solids by volume

$\frac{1490\,cy}{shift} \cdot \frac{27\,ft^3}{cy} \cdot \frac{7.48\,gal}{ft^3} \cdot \frac{shift}{8\,hr} \cdot \frac{1\,hr}{60\,min} = 626\ gpm$

Equipment cost for 200 gpm belt filter press = \$200,000 (vendor estimate)
Use $x^{.6}$ rule to estimate cost for 626 gpm unit

$$Cost = (\$200{,}000)\left(\frac{626}{200}\right)^{.6} = \$396{,}603 \sim \$400{,}000$$

Assume \$2 million to install, engineer, build, etc., ∴ total capital = \$2,400,000

ASSUME ANNUAL OPERATING COST @ 10% CAPITAL OUTLAY = (.1)(2,400,000) = \$240,000/yr

Golder Associates	SUBJECT Mechanical Dewatering Cost Estimate		
	Job No. 923-A017 Ref.	Made by JAR Checked Reviewed [signature]	Date 2/16/93 Sheet 2 of 3

Need additional moisture loss in waste material to decrease moisture content from 20% to 10%. From Page 1 weight of water per shift 72576 lb, ∴ half of total water needs to be removed = 36,288 lb/shift

Assume heated conveyor used to drive off 10% moisture

Estimate capital cost for heated conveyor to be $2.5-3.5 million assume $3 million, assume additional equipment such as graders, spreaders, compactors are an additional $700,000

Total capital outlay = $3,700,000

Annual OPERATING COST

Assume maintenance @ 5% of capital outlay = (3,700,000)(0.05) = $185,000/yr

Estimate power usage for heated conveyor

$36{,}228 \frac{lb}{shift} \cdot \frac{1060\ BTU}{lb} \cdot \frac{kwHr}{3412\ BTU} \cdot \frac{330\ shift}{yr} \cdot \frac{1}{.3\ eff.} \cdot \frac{\$\ 0.06}{kwHr} = \$877{,}381$ to vaporize water

$290{,}304 \frac{lb}{shift} \cdot (212-60)\left(\frac{0.17\ BTU}{°F\ lb}\right)\left(\frac{kwH}{3412\ BTU}\right)\left(\frac{330\ shift}{yr}\right)\left(\frac{\$0.06}{kwh}\right)\left(\frac{1}{.3\ eff}\right) = \$171{,}986/yr$ to heat soil

Σ Heating Cost = $1,049,367/yr

Total Annual Cost $1,234,367

Multiply by
27154.286
0.1
1.000165
1
1
1
1.000165
1.036377 × 10^{-4}
1.036086 × 10^{-4}
2.997930 × 10^{8}
0.999835
0.999835
1
1.03623 × 10^{-5}
1.03592 × 10^{-5}
0.01
0.001
2.997930 × 10^{7}
1
0.0001
1 × 10^{-4}
299793.0
1
15500.031
1.5500031 × 10^{4}
360
3600
0.373096
0.372991
1.2566371
1.2566371
3.767310 × 10^{10}
1.[illegible]6371
[illegible]7 × 10^{-8}
[illegible]37 × 10^{-8}
1.129413 × 10^{11}
1.256637 × 10^{-8}
1 × 10^{-8}
3.9370079 × 10^{-9}
0.0001
0.1
0.000165076373
0.000155316413
0.024710538
1
1076.3910
1076.3867
100
3.8610216 × 10^{-4}
1.01325
76
1033.26
1.01325 × 10^{6}
33.8995
1033.23
29.9213
1.03323
760
14.6960
1.05811
760
9.31395 × 10^{8}
1.66024 × 10^{-24}
9.31141 × 10^{8}
1.65979 × 10^{-24}

To convert from	To	Multiply by
Bags (Brit.)	Bushels (Brit.)	3
Barns	Sq. cm	1 × 10^{-24}
Barrels (Brit.)*	Bags (Brit.)	1.5
"	Barrels (U.S., dry)	1.415404
"	Barrels (U.S., liq.)	1.372513
"	Bushels (Brit.)	4.5
"	Bushels (U.S.)	4.644253
"	Cu. feet	5.779568
"	Cu. meters	0.1636591
"	Gallons (Brit.)	36
"	Liters	163.6546
Barrels (petroleum, U.S.)	Cu. feet	5.614583
"	Gallons (U.S.)	42
"	Liters	158.98284
Barrels (U.S., dry)	Barrels (U.S. liq.)	0.969696
"	Bushels (U.S.)	3.2812195
"	Cu. feet	4.083333
"	Cu. inches	7056
"	Cu. meters	0.11562712
"	Quarts (U.S., dry)	105
Barrels (U.S., liq.)	Barrels (U.S., dry)	1.03125
"	Barrels (wine)	1
"	Cu. feet	4.2109375
"	Cu. inches	7276.5
"	Cu. meters	0.11924047
"	Gallons (Brit.)	26.22925
"	Gallons (U.S., liq.)	31.5
"	Liters	119.23713
Bars	Atmospheres	0.986923
"	Baryes	1 × 10^{6}
"	Cm. of Hg (0°C.)	75.0062
"	Dynes/sq. cm	1 × 10^{6}
"	Ft. of H_2O (60°F.)	33.4883
"	Grams/sq. cm	1019.716
"	In. of Hg (32°F.)	29.5300
"	Kg./sq. cm	1.019716
"	Millibars	1000
"	Pounds/sq. inch	14.5038
Baryes	Atmospheres	9.86923 × 10^{-7}
"	Bars	1 × 10^{-6}
"	Dynes/sq. cm	1
"	Grams/sq. cm	0.001019716
"	Millibars	0.001
Bels	Decibels	10
Board feet	Cu. cm	2359.7372
"	Cu. feet	0.833333
"	Cu. inches	144
Bolts of cloth	Linear feet	120
"	Meters	36.576
Bougie decimales	Candles (Int.)	1.00
B.t.u.	B.t.u. (IST.)**	0.999346
"	B.t.u. (mean)	0.998563
"	B.t.u. (39°F.)	0.994982
"	B.t.u. (60°F.)	0.999689
"	Cal. *gm.*	251.99576
"	Cal., *gm.* (IST.)	251.831
"	Cal., *gm.* (mean)	251.634
"	Cal., *gm.* (20°C.)	252.122
"	Cu. cm.-atm	10405.6
"	Ergs	1.05435 × 10^{10}
"	Foot-poundals	25020.1
"	Foot-pounds	777.649
"	Gram-cm	1.07514 × 10^{7}
"	Hp.-hours	0.000392752
"	Hp.-years	4.48347 × 10^{-8}
"	Joules	1054.35
"	Joules (Int.)	1054.18
"	Kg.-meters	107.514
"	Kw.-hours	0.000292875
B.t.u.	Kw.-hours (Int.)	0.000292827
"	Liter-atm	10.4053
"	Tons of refrig. (U.S. std.)	3.46995 × 10^{-6}
"	Watt-seconds	1054.35
"	Watt-seconds (Int.)	1054.18
B.t.u. (IST.)	B.t.u.	1.00065
B.t.u. (mean)	B.t.u.	1.00144
"	B.t.u. (IST.)	1.00078
"	B.t.u. (39°F.)	0.996415
"	B.t.u. (60°F.)	1.00113
"	Hp.-hours	0.000393317
"	Joules	1055.87
"	Kg.-meters	107.669
"	Kw.-hours	0.000293297
"	Kw.-hours (Int.)	0.000293248
"	Liter-atm	10.4203
"	Watt-hours	0.293297
"	Watt-hours (Int.)	0.293248
B.t.u. (39°F.)	B.t.u.	1.00504
"	B.t.u. (IST.)	1.00439
"	B.t.u. (mean)	1.00360
"	B.t.u. (60°F)	1.00473
"	Joules	1059.67
B.t.u. (60°F.)	B.t.u.	1.00031
"	B.t.u. (IST.)	0.999657
"	B.t.u. (mean)	0.998873
"	B.t.u. (39°F.)	0.995291
B.t.u./hr	Cal., *kg.*/hr	0.251996
"	Ergs/sec	2.928751 × 10^{6}
"	Foot-pounds/hr	777.649
"	Horsepower	0.000392752
"	Horsepower (boiler)	2.98563 × 10^{-5}
"	Horsepower (electric)	0.000392594
"	Horsepower (metric)	0.000398199
"	Kilowatts	0.000292875
"	Lb. ice melted/hr	0.0069714
"	Tons of refrig. (U.S. comm.)	8.32789 × 10^{-5}
"	Watts	0.292875
B.t.u./min	Cal., *kg.*/min	0.251996
"	Ergs/sec	1.75725 × 10^{8}
"	Foot-pounds/min	777.649
"	Horsepower	0.0235651
"	Horsepower (boiler)	0.00179138
"	Horsepower (electric)	0.0235556
"	Horsepower (metric)	0.0238920
"	Joules/sec	17.5725
"	Kg.-meters/min	107.514
"	Kilowatts	0.0175725
"	Lb. ice melted/hr	0.41828
"	Tons of refrig. (U.S. comm.)	0.00499673
"	Watts	17.5725
B.t.u. (mean)/min	B.t.u. (mean)/hr	60
"	Cal., *kg.* (mean)/hr	15.1197
"	Cal., *kg.* (mean)/min	0.251996
"	Ergs/sec	1.75978 × 10^{8}
"	Foot-pounds/min	778.768
"	Horsepower	0.0235990
"	Horsepower (boiler)	0.00179396
"	Horsepower (electric)	0.0235895
"	Horsepower (metric)	0.0239264
"	Joules/sec	17.5978
"	Kg.-meters/min	107.669
"	Kilowatts	0.0175978
"	Lb. ice-melted/hr	0.41888
B.t.u./lb	Cal., *gm.*/gram	0.555555
"	Cu. cm.-atm./gram	22.9405
"	Cu. ft.-atm./lb	0.367471
"	Cu. ft.-(lb./sq. in.)/lb	5.40034
"	Foot-pounds/lb	777.649
"	Hp.-hr./lb	0.000392752

* Barrel (Brit., liq.) = Barrel (Brit., dry)
** International Steam Table.

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APPENDIX B

LANDFILL SIZE REQUIREMENTS

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LANDFILL SIZE REQUIREMENTS

The capital cost of the landfill is dominated by the cost of the liner. The unit cost of disposal, expressed in $/CY of waste, can be reduced by increasing the efficiency of the liner expressed in cubic yards of air space per square foot of installed liner (CY/sq ft). The most efficient landfill shape is one that most closely approximately a sphere, which has the greatest volume to surface ratio of any geometric shape. Thus, a square and deep landfill would be most efficient. The efficiencies of various landfill dimensions are presented in Table B-1.

Table B-1. Landfill Liner Efficiency as Function of Landfill Dimensions.

FLOOR LENGTH (ft)	FLOOR WIDTH (ft)	DEPTH (ft)	LINER EFFICIENCY (CY/sq ft) (1)
1000	500	33	0.94
1300	350	33	0.91
1700	250	33	0.87
2000	200	33	0.84
2400	150	33	0.80
3000	100	33	0.73
500	500	50	1.20
700	350	50	1.19
900	250	50	1.14
1100	200	50	1.11
1300	150	50	1.06
1600	100	50	0.99
2000	50	50	0.87
200	200	100	1.54
300	150	100	1.55
(1) For a total landfill volume of 750,000 CY			

The table shows that square and deep landfills are the most efficient. However, practical considerations dictate other shapes. A deep landfill would require a steep and/or spiraling access ramp which would be impractical. Similarly, square landfills require steep access ramps which can become inaccessible during bad weather. The square deep landfills have very small initial areas making them impractical for alternatives which require large areas for activities such as evaporation or fill traffic. They are also difficult to construct and close in phases.

The benefits of high liner efficiencies are relatively modest as shown in Table B-1. For this reason, the alternative designs assume a landfill with a floor width in the range of 200 to 300 ft, which provides adequate space to turn large trucks and operate equipment. The depth is limited to 33 ft, although modest variations in the depth would not adversely affect the design.

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